NEW SOUTH WALES.

DEPARTMENT OF MINES.

GEOLOGICAL SURVEY.

E. F. PITTMAN, A.R.S.M., Government Geologist.

MINERAL RESOURCES
No. 15.

THE TUNGSTEN-MINING INDUSTRY IN NEW SOUTH WALES.

BY

J. E. CARNE, F.G.S.,
ASSISTANT GOVERNMENT GEOLOGIST.

With Maps, Plates, &c.

1911.

SYDNEY: W. A. GULLICK, GOVERNMENT PRINTER.

1912.

[2s. 6d.]

†49—a

PLATE I.

Govt. Printer.

Photograph of Specimen from Fielder's Hill Quarry, showing Intrusions of Ore-rock (light-coloured), in Sedimentary Rock (dark-coloured). Size, 9½ in. by 7 in.

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LETTER OF TRANSMITTAL.

Department of Mines,
Sydney, 11th November, 1911.

Sir,

I have the honor to submit for publication a pamphlet on the Tungsten Mining Industry in New South Wales, by Mr. J. E. Carne, F.G.S., Assistant Government Geologist.

This work is really a third edition of Mr. Carne's original publication on Tungsten (No. 2 of the Mineral Resources Series). It has been amplified and brought up to date, and now contains much information which will be found useful by those engaged in mining for Wolfram and Scheelite. A considerable amount of attention has been paid to the Torrington District or Mole Tableland, where Tungsten minerals are most abundant.

I have the honor to be,

Sir,

Your obedient Servant,

EDWARD F. PITTMAN,

Government Geologist.

The Hon. Alfred Edden, Esq.,
Minister for Mines.

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INTRODUCTION.

The Writer in 1898 prepared a small pamphlet (Mineral Resources, No. 2) dealing with tungsten in New South Wales, which was reprinted the same year. At that date wolfram and scheelite mining was only just beginning, having received a stimulus from a modest advance in values compared with the present.

As this branch of mining is becoming an important adjunct to the State mineral industry, and an attempt is being make to work low grade deposits on a large scale, a third edition is deemed advisable.

Advantage was taken of the Writer's recent examination of the associated stanniferous areas (Mineral Resources, No. 14), to collect data in connection with tungsten ores and mining, the gist of which is embodied in the following pages.

In the map of the Torrington or Mole Tableland wolfram field, accompanying this work, the amended boundary of the Permo-Carboniferous inlier—originally surveyed by Professor T. W. E. David in 1884–5—has been adopted from a recent geological survey by L. A. Cotton, B.Sc., who is engaged on a work dealing with the genesis of these deposits.

Though the metal tungsten was probably reduced from its ores between 1781 and 1783 by either (or both) Scheele or the De Elhuyar brothers* ; and tungsten-iron alloys produced in 1855–6† its utilization in the industrial arts on an extensive scale is of very recent date, prior to which its ores were in small demand, and of comparatively little value.

Its gradual use as an alloy with steel for production, principally, of superior tool-steels (possessing the property of retaining temper at high speeds and temperatures); and also—according to common belief—in the manufacture of armour plate, has raised tungsten to a high place in metal values, ranking close to tin.

Being such a commercially new metal its literature is scanty, and distributed; the object of the present work is to collect in handy form items of special interest from published reports and articles, and to give a connected account of the metal, its ores, mining, concentration, metallurgy and uses, for the benefit of those interested in the local production of tungsten ores, to whom the literature of the subject is not easily available. No apology is therefore needed for liberal quotations from previous writers.

Touching the great diversity of opinion regarding use of tungsten in armour-plate, it may be that international rivalry in production of offensive and defensive munitions of war prevents the full facts being known.

Commercial attention was first directed to tungsten ores in New South Wales in 1890. Prior to this they had a nominal quoted value of about £12 per ton, but there was no production.

In 1890, Messrs. Sternberg and Deutsch, of Martinikenfelde, *viâ* Berlin, made personal inquiry in the New South Wales Court at the London Mining Exhibition, and offered £30 per ton for ore containing 70 per cent. of tungstic oxide (commonly defined as tungstic acid), delivered in Berlin. This intimation of rapid advance in value (announced in the State through the Department of Mines) caused considerable activity in prospecting for wolfram, the only ore then known to occur in appreciable quantities. Its

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* R. A. Hadfield, Journ. Iron and Steel Institute, 1903, p. 27. † *Ibid*, p. 40.

presence had been noted chiefly in the tinfields, where it was hitherto unwelcome. Now the tungsten associates of the tin-ore received attention, but proved mostly unremunerative, owing to small dimensions of the concentrated bunches or lean dissemination of more distributed particles.

Prior to 1898 the output of tungsten ores was so slight that separate entries were not adopted in the statistics of the Department of Mines, a number of small returns being included under "sundry minerals."

Mr. E. F. Pittman, Government Geologist, however, has published the following figures for the interim :*—

—	Tons.	Value.	—	Tons.	Value.
		£			£
1891	7·00	70	1896	...	...
1892	...	...	1897	...	...
1893	1·38	14	1898	10·25	310
1894	...	...	1899	159·00†	3,710
1895	5·00	88			

Notification of increased value, however, resulted in samples being forwarded to the Departmental Laboratory for testing purposes from near Berridale, Burrowa, Bundarra, Frogmore, Mount Hope, and New England, fifteen tests being made.

In 1892 twenty-two assays were made, Hillgrove scheelite being for the first time represented, samples from this field yielding from 38 to 71 per cent. of tungstic oxide.

Mining for scheelite, however, did not begin until 1898, when 1 ton 3 cwt., valued at £30, was reported to have been raised from a small bunch, which soon became exhausted.

In 1899 the Hillgrove scheelite lodes attracted a good deal of attention, 74 tons of dressed ore, valued at £2,910, being exported.‡

1900–1–2 appear to have been barren of production, owing to the extremely low value of the mineral, no exports from Hillgrove being recorded.

From 1903 mining for scheelite and wolfram has been continuous, bringing the total productions to the end of 1910 up to the following figures :—

Scheelite, 1,080·75 tons, valued at ... £90,892
Wolfram, 929·85 tons, valued at ... 88,068

Total, 2,010 tons, valued at ... £178,960

Hillgrove is about 3,350 feet above sea-level, and the average rainfall is about 40 or 41 inches per annum.§

It is situated 19 miles from the nearest railway-station—Armidale—by road, 274 from the port of Newcastle, and 378 from Sydney by rail.

The production of wolfram for 1911 should show a marked increase, because of high values, renewed activity, and increasing milling and concentrating capacity in the Mole Tableland, where the principal deposits are situated.

Mole Tableland is a plateau, having an elevation of 3,600 to 3,700 feet above sea-level, with peaks rising to 4,000 feet. The wolfram mines are situated about 25 miles from Deepwater railway station, 382 from the

* Mineral Resources, N. S. Wales, 1901, p. 303. † Including 74 tons of scheelite from Hillgrove.
‡ E. F. Pittman, Min. Resources N.S.W., 1901, p. 301.
§ E. C. Andrews, Min. Resources No. 8, Rept. on the Hillgrove Gold-field, 1900, p. 13.

Port of Newcastle, and 490 from Sydney by rail. The mean summer temperature is probably about 65° to 68°, mean winter about 40° to 44°. The annual rainfall averages about 35 to 40 inches.

The Mole Tableland or Torrington wolfram mines are favourably situated as regards useful timbers for all purposes. Mr. R. H. Cambage, F.L.S., has published notes on the flora of Torrington and the neighbourhood of the wolfram mines generally.*

> "The country round Stannum and Torrington, which ranges from 3,400 to about 4,000 feet, consists chiefly of hills composed of acid granite, often known as tin-granite, from its association with valuable tin deposits. Quartz is so abundant that the disintegration of this coarse granite results in the production of a soil as sandy as that derived from the weathering of the Triassic sandstone near Sydney and on the Blue Mountains. The effect of geological influence on the vegetation is very apparent on this particular area, for many Sydney species are thriving here, imparting to the locality much of the appearance of a typical sandstone flora."

From Mr. Cambage's list the following are noted as the best for building and mining timber :—

Eucalyptus macrorhyncha ...	(Red stringybark).
,, *eugenioides* ...	(White stringybark).
,, *Andrewsi*	(Blackbutt).

The following are noted as useful for fuel, mining props, &c. :—

Eucalyptus capitellata	(Brown stringybark).
,, *tereticornis*	(Forest red gum).
,, *Stuartiana*	(White peppermint).
,, *Deanei*	(Brown gum).
,, *Bancrofti*	(Brittle or cabbage gum).
Casuarina suberosa	(Black oak).

The Gulf section of the Emmaville Tinfield also furnishes a small and irregular output of wolfram, chiefly from small bunches and thin veins, which are crushed and concentrated by hand with primitive appliances.

Pulletop, in the Wagga district, and Wilson's Downfall, on the Queensland Border, also supply small parcels at irregular intervals.

Hogue's Creek, near Dundee, has recently also become a small producer, in consequence of the erection of a milling plant.

Until the Mole Tableland or Torrington wolfram deposits were opened on a fairly large scale, the State export of wolfram was won from small rich bunches (or "bungs") and thin veins, by individual miners chiefly, who confined their attention to these richer portions.

Plants are now being laid down to work extensive low-grade deposits on a large scale by quarrying, truck-haulage, stamp and grinding mills, and labour-saving concentrating appliances.

If the market value of the metal remains fairly constant at present rates, the outlook of the industry is hopeful for large-scale operations.

The scheelite lodes of the Hillgrove district will also continue to supply their quota to the State output of tungsten ores, but the nature of the deposits—as thin veins and small lenses—restricts mining to comparatively

* Proc. Linn. Society N.S. Wales, 1908, XXXIII, pp. 452–472.

limited enterprises, chiefly in the hands of working miners. The areas held range from ordinary claims to leases of 1 to 5 acres, and very rarely of 10 and 20 acres.

The high value of the mineral in March, 1911—when this field was visited by the writer—had renewed activity; practically little capital, save labour, being needed for "gouging" out and dressing the small superficial "makes" of mineral in the numerous veins outcropping in the granite area at Hillgrove. Moreover, the output, however small, can be readily converted into cash locally.

The market grade for wolfram is usually computed at 70 per cent., and 72 for scheelite; these percentages are, however, subject to contract arrangements, and are sometimes even exceeded. In the United States returns, wolfram concentrates are calculated at 60 per cent. tungstic trioxide.

The grades of the samples of concentrates from tables, vanners, and buddles taken for analysis in connection with this work indicate the "first-run" of the concentrates and not the market grades; where necessary, the latter is secured by blending, or, sometimes, by reconcentration.

ACKNOWLEDGMENTS.

In the preparation of this issue of the Mineral Resources, the Writer is, as usual, indebted to Mr. O. Trickett, L.S., for drafting work; Mr. G. W. Card, A.R.S.M., for petrological examination and description of rock specimens; Mr. J. C. H. Mingaye, F.I.C., F.C.S., Mr. H. P. White, and Mr. W. A. Greig, for analytical work; Mr. W. S. Dun, Palæontologist and Librarian for editing and indexing; and Messrs. M. Morrison, and C. Murton, field assistants, the first for descriptions of the Nundle and Mount Tallabung deposits, the latter for assistance in statistical research.

The Writer is indebted to the Torrington Ore Company, Limited, the Rockvale Wolfram, and the Torrington Wolfram Companies, Limited, for assistance and statistical information.

He is specially indebted to Mr. T. H. Nicholas, Manager of the Torrington Mines, for personal assistance, and for kindly taking photographic views of the property. Mr. H. P. Fletcher, Manager of the Rockvale Mines, Mr. G. P. Lock, of the Torrington Wolfram Mines, and Mr. A. James, Manager of the New Hope Mine, have also assisted and supplied views illustrating the mines under their control.

Messrs. F. H. Gibson, E. McNamara, H. G. Madricks, and J. Usher, of Hillgrove; Mr. H. Cornell, mill master, Torrington Wolfram Concentrating Plant, have also supplied information.

II.—TUNGSTEN—ITS PROPERTIES, METALLURGY, AND USES.

R. A. HADFIELD, in a paper on "Alloys of Iron and Tungsten,"* gives a most interesting history of tungsten, including the origin of the name, and discovery of the metal.

His conclusions as to the vexed question of discovery are given in the following extract:—After referring to the brothers De Elhuyar, he states :—

> "The author, therefore, cannot but think that they were really describing (in a paper read before the Academy des Sciences de Toulouse, 24th March, 1784, entitled 'A Chemical Analysis of Wolfram and Examination of a new metal which enters into its composition') the results of experimental work instituted by Scheele, and that the primary discovery was due to Scheele in 1781, that Bergman followed with further research work a little later, and finally the brothers De Elhuyar in 1783 completed the work of the more prominent Swedish investigators.† . .
>
> "Kirwan says (in his 'Elements of Mineralogy,' 1784), that the constituent parts of tungsten were discovered by Bergman and Scheele nearly at the same time, the first publication being by Scheele in the Swedish Memoirs, 1781. It may be mentioned that Kirwan speaks of the ore, but did not appear to be aware of the discovery of the separation of the metal itself."

A summary of the chief points regarding tungsten appears in Dr. Adelbert Rössing's *Geschichte der Metalle* (1901). This is specially interesting, as it gives the names of those who carried out research work at a still earlier date than Scheele and Bergman. He states :—

> "The miners at an early date had already, in their own language, given the name Wolfram to a black crystalline mineral, which they found in fairly abundant quantities in tin ore mines, probably from 'Wolfish,' or the devouring ore, because it caused great loss in the working of tin ore. Later it was considered an impure tin ore, also as a manganese ore. Another mineral of a bright white colour also found with tin ore (Scheelite.—J.E.C.), was, on account of its great weight, named tungsten, by Cronstedt, in 1755. This material, he, in 1758, perceived contained no tin, but in combination with an unknown ore, showed a limy iron ore. Kaim's experiment in 1770, in which he claimed to have got a metal from this material, was proved to be incorrect. In 1781, Scheele discovered that tungsten, besides lime, contained a peculiar acid which Bergman declared was a metallic lime. The brothers De Elhuyar, in 1783, discovered this acid also in Wolfram, reduced the metal from it, and named it after this mineral Wolfram or tungsten mineral. Werner gave to it the name 'Scheel,' and Berzelius that of 'Wolframium.'"‡

T. L. Walker states the mineral which is now called wolframite was named *Lupis spuma* by Agricola in the early part of the 16th century.§

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* Journ. Iron and Steel Institute, II, 1903, pp. 14-79. † *Ibid.* p. 24. ‡ *Ibid*, p. 27.

§ Report on the Tungsten Ores of Canada. Dept. of Mines, Canada, 1909, p. 3.

Physical Characters of Tungsten.

Hadfield states that :—

"As far as we know the metal tungsten, like chromium, is not malleable. If an absolutely pure metal could be obtained, possibly this statement might have to be modified, but the purest forms which the author has been able to obtain possess hardness, brittleness, and are not ductile either in the ordinary or heated condition.

"The following table gives particulars of the physical constants of the metal :—

Atomic weight	183·60
,, volume	9·53
,, density	105·00
Specific gravity	19·26
,, heat (Regnault)	0·036

"According to Mendeleef, the melting-point of the metal is 1,500° C.

"It may be interesting to add for comparison the same data regarding molybdenum, which is supposed to be a metal possessing similar properties :—

Atomic weight	95·90
,, volume	11·10
Specific gravity	8·60
,, heat	0·072

"The metal not being obtainable in a form that can be used for electrical or heat conductivity experiments, its properties in these respects are not known, except approximately.*

"The metal tungsten does not oxidise in either dry or wet air, but is easily converted into a trioxide (WO_3) by heating to low redness in oxygen, air, or steam. The oxide is of a yellow colour, but small quantities of alkalies cause it to assume a green tint."†

According to O. J. Steinhart,‡ the physical properties of the metal tungsten depend on the manner of its preparation.

"Reduction by hydrogen at dull redness gives an amorphous steel-grey powder of a fine lustre. The reduction of tungstic acid by potassium by Wohler's method gives a more brilliant crystalline powder. By electrolyzing molten sodium tungstate, Zetnow obtained the metal in the state of a black amorphous powder.

"Tungsten is difficultly fusible, its melting point having been recently given as 2,800 to 3,000 deg. C. It can be drilled and filed easily, and is not magnetic. Its density depends on the method of preparation, varying from 17 to 18 for the pulverised varieties. Pure tungsten melted in the electric furnace has a density of 18·7. Heated to 1,000 deg. C., and compressed under a pressure of 200 kg. per sq. cm. (200 atmospheres) gives a density as high as 18·92. Its specific heat is about 0·034 deg. C., and increases with the temperature. Its electrical resistance as determined by use is 86 x 10^6=0·000086 ohms per centimeter at 10 deg. C.

"*Chemical Properties.*—Tungsten is attacked by fluorine at ordinary temperatures with intumescence, forming a volatile fluoride. Dry chlorine attacks it at about 300 deg. C., forming the hexachloride;

* Journ. Iron and Steel Institute, II., 1903, p. 45. † *Ibid.*, p. 34.
‡ The Mineral Industry, 1908, XVII, pp. 832-835.

moists chlorine gas forms the red oxychloride. Bromine acts on it only at low redness, forming the pentabromide; iodine attacks it only at a bright cherry red. Oxygen, either dry or moist, has only a feeble action at ordinary temperatures; however, the metal blackens little by little in the air. At redness, tungsten is attacked by oxygen, forming tungstic acid. Melted sulphur slowly transforms tungsten into sulphide. Nitrogen has no action at redness; the vapour of phosphorus attacks powdered tungsten at redness. In the electric furnace, carbon, boron, and silicon unite with tungsten to form carbides, borides, and silicides.

"Tungsten is not sensibly attacked by water at ordinary temperatures; it is attacked rapidly by vapour of water at redness. Hydrophoric and sulphuric acids attack it slowly; nitric acid and aqua regia transform it into tungstic acid. Carbon bisulphide and hydrogen sulphide attack tungsten at redness, forming the bisulphide. Several fused oxidising agents, such as lead peroxide and potassium chlorate, attack the powdered metal with incandescence. Fused sodium carbonate and nitrate of potassium oxidises it rapidly, forming potassium tungstate. Arsenide of tungsten heated with copper out of contact with air up to the melting-point of copper is completely decomposed, forming copper arsenide and metallic tungsten. Tungsten forms compounds with boron, carbon, silicon, and alloys with alumina, nickel, iron, manganese, chromium, and molybdenum.

"The manufacture of metallic tungsten powder 96–98, as now employed by the steelmaker, is in the hands of about half-a-dozen German makers, and seems to have first been perfected at some of the Hanoverian works. In England, the Tungsten and Rare Metals Company (Limited) began the manufacture of metals of the following composition:—

	Per cent.	Per cent.
Tungsten (W)	97·02	98·63
Silicon (Si)	0·72	0·32
Carbon (C)	0·32	0·12
Alumina (Al)	0·47	0·21
Iron (Fe)	0·61	0·59
Magnesium (Mg)	0·32	0·13*
Manganese (Mn)	0.16	......
Sulphur (S)	Nil	......
Phosphorus (P)	Nil	......
Oxygen, &c. (O)	0·33	.....
	100·00	100·00

"Briefly, the production of the metal is carried out as follows:—The ore is first ground to a fine powder, and heated in a reverberatory furnace with the necessary quantity of sodium carbonate in order to form tungstate of soda. The melt, which also contains the FeO, MnO, Al_2O_3, SiO_2, and any SnO_2 present, is again crushed, leached with boiling water, pressed, and the above mentioned oxides left behind in the filter press in which the last operation is performed. If the furnacing has been carried on correctly, not a trace of tin need go into the solution; in fact, tin is often recovered from the residues. From the sodium tungstate the yellow WO_3 is thrown down by means of hydrochloric acid. The tungstic acid is dried and reduced in crucibles to metallic tungsten, which should not contain more than 0·5 per cent. of carbon as sent to the steel-makers. The manufacture is a lengthy and complicated one, and requires careful and highly-trained chemical supervision. . . . .

*Including calcium and oxygen.

"Without going fully into the cost of the manufacture of tungsten by the process outlined above, it may be taken to be between £80 and £100 per ton of metal made, including the manufacturer's profit. The yield is by no means a theoretical one, as it requires from 140 to 145 units of WO_3, as compared with the theoretical consumption of 120 units, to produce 100 parts of 96 to 98 per cent. tungsten. If, therefore, we take the present price of ore at 26s. per unit, we have the following :—(26s. × 140) + £90 = £272 per ton.

"Besides tungsten powder, ferrotungsten is now produced regularly in France by Girol and others in the electrical furnace, and for some purposes may be used with advantage, although it is not materially cheaper, as far as its tungsten contents are concerned, than tungsten powder.

"Ferrotungsten is produced in three grades, with varying carbon contents as follows :—

	No. 1. Per cent.	No. 2. Per cent.	No. 3. Per cent.
Tungsten	85·15	79·48	71·80
Iron	14·12	18·60	24·35
Carbon	0·45	1·49	2·58
Silicon	0·13	0·16	0·36
Manganese	0·085	0·21	0·78
Phosphorus	0·018	0·017	0·008
Sulphur	0·021	0·016	0·02
Aluminium	......	0·001	0·07
Copper	......	......	0·008

"The manufacturers of tungsten steels seem to prefer the powder, as it is easily added to the steel and can be relied upon as to composition. The annual consumption in Sheffield alone is about 1,000 to 1,500 tons, practically all of which is used for high speed rapid cutting tool steels."

R. A. Hadfield states that :—

"The mineral wolfram (wolframite), which is composed of tungstate of iron and manganese (MnO), can be reduced by charcoal at a high temperature. The ore is first roasted, and after being treated by diluted acids it is washed by water. Such a treatment will at once eliminate sulphur and arsenic. After careful drying, the purified mineral is strongly heated in a crucible lined with charcoal, whereby the tungstic acid is reduced to metallic tungsten, while at the same time the production of a compound of carbon, iron, and manganese will take place. This mass is then used for alloying with steel."*

E. J. Biermann, of Hanover, claims to have produced the first ferrotungsten alloy in 1866, which contained 25 per cent. of tungsten (*Ibid*), but Hadfield gives earlier references to its production.

R. A. Hadfield states that :—

"Spanish tungsten ore is being reduced by the Tungsten and Rare Metals Company, Limited, Queen's-road Station, Battersea, London. The ore is first crushed in ball mills, and then roasted in the presence of soda, with the object of producing tungstate of sodium. This substance is leached out, and then, by the addition of an acid, the tungstic acid is liberated from the soda and separated out by a filter press. The tungstic acid is reduced with charcoal in crucibles.

* Journ. Iron and Steel Institute, II, 1903, p. 36.

"The Tungsten Company has kindly given the Author particulars of their methods, which are as follows:—

"There are three steps in the manufacture of tungsten from wolfram. They consist as follows:—

(1.) Tungstate of soda is first prepared by heating together a mixture of ground ore and sodium carbonate. If this operation is carried out under proper conditions, the extraction of the tungsten from the ore is total. At the same time the presence of tin and silica in the ore necessitates precautions being taken to avoid rendering these soluble together with the sodium tungstate, so that even at this early stage the metal may be spoilt by unskilled furnacing.

(2.) The sodium tungstate thus formed is dissolved in water and separated from the iron, alumina, manganese, tin, and silica, and then treated with acid to precipitate the tungstic oxide (WO_3).

"The tungstic oxide is then washed free from soda salts and dried.

"In this step very considerable losses may be experienced through the formation of hydrated tungstic oxide, which is soluble, and is washed out with the waste soda salts and lost. Likewise any undecomposed sodium tungstate must be guarded against, as this gives rise to the well-known red crystals so often found in metallic tungsten. These are sodium compounds of tungstic acid."

(3.) The dry tungstic oxide is mixed with carbonaceous materials and submitted to high temperature in crucibles for reduction to metal. This operation need involve no loss if skilfully performed. Wrong mixtures or bad firing will very seriously reduce the yield of metal.

"A well-fired crucible, when opened, should be uniform throughout, with the exception of a thin layer of 'tops,' or undecomposed tungstic oxide and carbon on the surface, which can easily be removed before emptying the crucible.

"Freedom from injurious impurities depends mainly upon the skill exercised in the first two operations, while the percentage of tungsten in the finished product naturally depends largely upon the third step."*

Dr. Adolf Gurlt states that:—

"Wolfram steel was made as early as 1855 by Dr. F. Koeller, at Reichramming, in Austria, and a few years later was imitated by Mushet† who introduced it by the name of 'Mushet's Special Steel' to the general public. Professor Heeren, of Hanover, as well as Professor L. Gruner, of Paris, investigated its remarkable properties, and found when forged red-hot and cooled slowly it possesses an extraordinary degree of hardness, which, however, gives way to softness when plunged red-hot into cold water, quite contrary to most other species of steel."‡

* Journ. Iron and Steel Institute, No. II, 1903, pp. 38-39.

† He obtained his first patent for tungsten steel in 1857, according to O. J. Steinhardt. The Mineral Industry, XVII, 1908, p. 833.—J.E.C.

‡ Trans. Am. Inst. Mining Engineers, XXII, Pt. I, 1894, p. 237.

Hadfield states that :—

"As is well known, tungsten has been used for many years in the manufacture of self-hardening steel, that is, steel which could be rendered hard enough to keep a cutting edge by means of treatment and without subsequent water quenching. If such steel was dipped in water whilst red-hot it would split or crack. The tungsten percentage in such steel has usually been between 5 and 8 per cent., carbon 1·50 to 2·30 per cent. The following are analyses of such steel, the first two on the list being of the well-known Mushet steel :—

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Tungsten.
2·30	1·05	......	......	2·57	6·12
2·00	1·60	0·02	0·04	1·72	8·22
2·05	0·79	0·04	0·04	2·30	8·04
1·67	0·33	......	......	2·53	5·74
2·35	0·15	......	......	3·38	11·02

"Further improvements by American works in such steel have been made by increasing the tungsten to very high percentages, 15 to 20 per cent., and also adding chromium, and, singular to say, such steel shows a remarkably small percentage of carbon for tool steel, viz., about 0·70 per cent." *

Hardening by Quenching.—The same authority refers to Osmond having found—

"That by a gradual increase of the temperature a point occurred where the steel was hardened by quenching, although when heated to a *lower* temperature, and quenched at the same temperature, no hardening action occurred. In other words the same steel heated to 830° and quenched at 630° remained *unhardened*, but when taken first to 1310° and quenched at even a lower temperature, viz., 555°, it was *very hard*. As Mr. Osmond remarks, it is thus seen that in quenching this steel at about 600° there can be obtained a metal very hard, quite soft, or of medium hardness, according to the temperature of the first heating." . . .

"This special 'quick speed' steel requires much care in forging, as owing to the high percentage of carbon present it is naturally easily overheated and burned; hence the later types of tungsten steel known as 'quick speed' cutting steel contain much lower percentages of carbon, but nearly twice the amount of tungsten as compared with the older types of self-hardening steel. Other elements, such as chromium, are also added in comparatively small quantities, and these combinations offer a steel the temper of which cannot be easily drawn even when approaching almost that of low red heat."†

F. H. Hess states that :—

"When lathe tools are made from tungsten steel, the lathes may be speeded up until the chips leaving the tool are so hot that they turn blue. It is said that about five times as much work can be done by a lathe built for such speeds and work and fitted with tungsten-steel tools as can be done by the same lathe with carbon-steel tools. Sixteen to 20 per cent. tungsten is ordinarily used in lathe tools."‡

* Journ. Iron and Steel Institute, II, 1903, pp. 66, 67. † *Ibid.*, pp. 68, 69.
‡ Min. Resources U. States, U. S. Geol. Survey, 1908, page 730.

J. M. Gledhill* states that a number of experiments were made with the tungsten content of high-speed steels :—

"Ranging from 9·0 per cent. to 27·0 per cent. From 9·0 per cent. to 16·0 per cent. the nature of the steel becomes very brittle, but at the same time the cutting efficiency is greatly increased, and about 16·0 per cent. appeared to be about the limit, as no better results were obtained by increasing the tungsten beyond this figure. Between 18·0 per cent. and 27·0 per cent. it was found that the nature of the steel altered somewhat, and instead of being brittle, it became softer and tougher, and whilst such tools have the property of cutting cleanly, they do not stand up so well.

"It was found that the presence of 0·5 per cent. to 3·0 per cent. of molybdenum in a high tungsten steel slightly increased the cutting efficiency, but the advantage gained is altogether out of proportion to the cost of the added molybdenum. . . . .

"An analysis of one of the best qualities of rapid steels produced by the Author's firm is as follows :—

	Per cent.
Carbon	0·55
Chromium	3·5
Tungsten	13·5

R. A. Hadfield, referring to Professor V. Leepin's (St. Petersburg) tests on the mechanical properties of tungsten and molybdenum steel, both made in a Siemens regenerative furnace, states that :—

"The molybdenum steel was found to be softer than the tungsten steel. Oil tempering and high heating after hardening increased the limit of elasticity in the steel. Oil tempering had a greater influence on the tungsten steel than on the molybdenum steel, but the latter was stronger after heating and water-hardening. Tungsten steel was more apt to split when worked, and broke sooner when bent cold. Its general properties were similar, but molybdenum steel stood forging and hardening better. The steel was made at the Putilof Ironworks, and the results were published in the Russian Mining Journal, 1897.")†

C. A. Edwards refers to—

"A steel containing carbon 0·68 per cent., chromium 3·01 per cent., tungsten 19·37 per cent., and silicon 0·04 per cent., as the hardest steel, so far as he was aware, that had been recorded."‡

Frank L. Hess§ states, in reference to the "widespread belief, based upon frequently published statements, that most of the tungsten mined went into armor-plate, and it was supposed that there was no cessation in the use of such steel by the United States and other governments. The Writer has been informed by the Ordnance Bureau of the Navy Department that tungsten is not now, and, so far as known to that Bureau, never has been, used in the manufacture of armor-plate in this country, and it is not known to have been so used in other countries, though it has probably been used in experimental armor-plates. One of the greatest essentials of armor-plate is its ability to resist shock, and this property is not imparted to steel by tungsten. Most armor-plate depends for its shock-resisting properties upon the addition of nickel and chromium to the steel from which it is made, and upon special treatment."

* Journ. Iron and Steel Institute, 1904, II, p. 131.
† Journ. Iron and Steel Institute, II, 1903, pp. 43, 44.
‡ Iron and Steel Institute, Vol. 21, 1908, p. 723.
§ Mineral Resources U. States, U. S. Geol. Survey, 1908, I, p. 721.

In support of this statement, the composition of steel employed in the Krupp process of armour-plate manufacture carried out at the Terni Steelworks may be quoted after U. F. Gregoretti*:—

	Per cent.
Carbon	0·31
Silicon	0·02
Sulphur	0·02
Phosphorus	0·01
Manganese	0·30
Nickel	3·90
Chromium	1·78

From the same Journal,† an earlier statement of composition is here given:—"Armour-plate, as now made, is a metal which, while varying slightly at different works, has an average composition closely approximating to the following:—

	Per cent.
Carbon	0·30
Manganese	0·35
Nickel	2·50
Chromium	0·60

The superiority of nickel-chrome-steel over tungsten steel is emphasised by Colonel L. Cubillo (Trubia, Spain) in a discussion of Hadfield's paper on "Alloys of Iron and Tungsten"‡:—

"From the point of view of the Ordnance Branch, it did not appear, however, that alloys of iron and tungsten could present the same degree of interest as those of iron and chromium and of iron and nickel. With the latter especially, tungsten alloys could not compare in importance where the manufacture of large guns was concerned, nor could it compare with either of the latter in the case of projectiles and armoured plate. The iron-nickel alloy appeared now to have been currently adopted in the construction of field artillery and for quick-firing guns up to a calibre of 5 to 6 inches. Its high elastic limit rendered it very suitable for this purpose, notwithstanding the difficulties which had to be contended with in forging the tubes and hoops, as had been observed in the arsenal of Trubia, in the process of manufacturing field guns. The advantages of the nickel alloy were, however, so great that they fully repaid any difficulties encountered in the forging and in the subsequent mechanical working."

Hadfield states that:—

"The presence of tungsten in an iron alloy, like manganese, chromium, silicon, aluminium, and nickel, greatly hinders or prohibits the welding together of specimens."§

He also draws attention to the fact that, "Unlike either iron-manganese or iron-nickel alloys, there is apparently no point where the maximum brittleness is reached and afterwards a return to toughness. In the two former steels there is a zone of brittleness, and, with further higher additions, a return to toughness. . . . .

"Iron-tungsten alloys, therefore, do not appear to show the peculiar exception found in nickel and manganese steels. They conform to the general rule that increasing quantities of an element added to an alloy already brittle do not restore the toughness."||

* Journ. Iron and Steel Institute, 1910, II, p. 498. † 1907, I, p. 516. ‡ Journ. Iron and Steel Institute, II, 1903, p. 94. § Journ. Iron and Steel Institute, II, 1903, p. 62. || Journ. Iron and Steel Institute, II, 1903, p. 51.

C. Baskerville, on the other hand, mentions armour plate as one of the uses to which tungsten is put as an alloy with steel, either by itself or with molybdenum and chromium, a product possessing great toughness and ability to resist shock.*

The Bulletin of the Imperial Institute contains an article on Occurrence and Utilisation of Tungsten Ores,† in which the use of tungsten in armour plates is referred in the following terms :—

> "The addition of a small quantity of tungsten toughens steel plate and renders it less liable to fracture. This property renders tungsten steel specially suitable for the manufacture of armour plate, projectiles, and firearms."

Captain Le Guen, of Brest, probably prior to 1869, made, according to R. A. Hadfield, experiments as to the effect of tungsten on charcoal iron used for cannon founding. The metal was found to possess greater resistance than even the best cannon iron.‡

In addition to its principal use (as an alloy with iron in the manufacture of tool steel), tungsten is used, in the form of acid salts, as a mordant in dyeing for rendering coloured cotton goods "fast" or washable, and linen and cotton, theatrical, or other properties non-inflammable; in the manufacture of stained and other papers ; in glass-making, weighting silks, &c.

Heinrich Ries states that the fluorescent properties of tungstate of lime make it useful in the Röntgen ray apparatus.§

Magnet Steel.—Hadfield states that :—

> "One very peculiar effect of the adding of tungsten to ordinary high carbon steel is that the retentiveness is greatly increased, hence its suitability for permanent magnet steel."||

He also states that :—

> "Unlike alloys of iron manganese and iron nickel, there is no falling off or decrease in the magnetic qualities by increasing additions of tungsten."¶

After noting that tungsten is specially well suited for making permanent magnets, the same authority adds :—

> "It would appear that the highest magnetic power attainable with the greatest retentivity would be reached with alloys containing 4 to 7 per cent. of tungsten."**

The usual composition of tungsten magnet steel, according to Hadfield, is :—††

Carbon	0·50
Manganese	0·60
Tungsten	4·50

W. L. Fleming‡‡ states that during 1909 :—

> "Considerable interest was manifested in the utilization of tungsten in manufactures. The Chemische Fabrik, Fuerth, Bavaria, now makes a ferro-tungsten powder, which is of high purity, and alloys readily with the metal, a much better product being made with greater ease and with less waste than with the use of metallic tungsten or ferro-tungsten in lumps. The research laboratory of the General Electric Company, at Schenectady, N.Y., has succeeded in producing pure tungsten, which is so ductile that it has been drawn into the finest wire, and which possesses extraordinary tensile strength.

* The Engineering and Mining Journal, 23rd January, 1909, p. 203. † Vol. VII, No. 3, 1909, p. 293. ‡ Journ. Iron and Steel Institute, II, 1903, p. 42. § Economic Geology, 2nd Ed., 1910, p. 565. || Journ. Iron and Steel Institute, II, 1903, p. 63. ¶ *Ibid.*, p. 51. ** *Ibid.*, pp. 63, 64. †† *Ibid.*, p. 66. ‡‡ The Mineral Industry, XVIII, 1909, p. 693.

"The outcome of this work should be important in the manufacture of the tungsten lamp, as the fragility of the filament has been one of the most serious drawbacks to the introduction of this lamp.

O. J. Steinhart states that :—

"Besides tool steel, tungsten is used for few other purposes. Permanent magnets for telephones are made of tungsten steel, and are said to answer well. Within the last two or three years a great number of patents have been taken out for the manufacture of metallic filaments for electric lamps. The so-called Osram lamp, which has a practically pure tungsten filament, is one of the best known examples. . . . .

"The essential feature of the patented process for producing these tungsten filaments consists of mixing the powdered metal into the form of a paste with an organic binding agent, such as, for instance, gum arabic—which, of course, is rich in carbon—and squirting this paste into a thread. The filaments afterwards go through various processes, by means of which all carbon is said to be removed, leaving the metal absolutely pure. These lamps consume only about one-third the amount of current of the ordinary carbon filament of the same candle-power. . . . One ton of 70 per cent. wolframite will suffice to make 18 million lamps."*

According to the Bulletin of the Imperial Institute† :—

"Considerable improvements have been made recently in the manufacture of the tungsten lamp, and it is now claimed that it has an efficiency of 1 to 1·2 watts per candle-power."

Dr. Adolf Gurlt states, in reference to wolfram and scheelite, that :—

"These minerals were employed in 1848 by the English chemist, Robert Oxland, for the preparation of tungstate of soda, to be used as a mordant in dyeing cloth, and, as proposed by Versmann and Lyon Playfair, for the impregnation of vegetable tissues, linen and cotton, to render them non-inflammable and almost fire-proof. The same compound, when free from impurities, such as tin, copper, arsenic, bismuth, and iron, is the basis of the manufacture of wolfram-metal and other preparations of tungstic acid and the oxides of barium, copper, chromium, or of blue oxide of wolfram, or the tungstate of wolfram oxide and soda. This last preparation has a shining bronze lustre, and like most of the other tungsten compounds, which are characterized by yellow, green, blue, pink, and gold colours, it is used in the manufacture of stained papers, &c."‡

R. A. Hadfield states that :—

"As regards the manufacture of tungsten compounds from wolfram, Oxland's method is generally adopted, the ore being fused with soda ash and sodium nitrate, in a reverberatory furnace, and the soluble sodium tungstate dissolved out and obtained by crystallisation."

"Roscoe states that metallic tungsten is then prepared by calcining an intimate mixture of tungsten trioxide and carbon in a covered crucible, and that it may also be obtained by reducing the same oxide in a current of hydrogen, or by reduction of the chloride in vapour of sodium. It has, however, not been made in the coherent condition. In order to obtain the pure metal, the pure bright canary-yellow-coloured trioxide is ignited in a platinum or porcelain tube to bright redness in a

* The Mineral Industry, XVII, 1908, pp. 834-835. † Vol. VII, No. 3, 1909, p. 294. ‡ Trans. Am. Inst. Mining Engineers, XXII, Pt. I, 1894, pp. 237, 238.

current of dry and pure hydrogen. The metallic powder thus obtained possesses a light bright grey metallic lustre, and has a specific gravity of 19·129 (Roscoe)."*

F. L. Hess states that tungsten is used in the manufacture of small crucibles for use in the electric furnace. These are made by mixing tungsten powder with a small amount of some carbonaceous paste, and pressing the mixture into the desired shape, after which it is sintered in an electric furnace. This makes a porous metallic vessel, as the particles will not melt sufficiently to run together. The crucibles when used are lined with an inert, infusible substance, such as thoria, for, when heated, tungsten combines with many substances.†

The same authority also records that:—

"Sodium tungstate has almost precisely the same rate of expansion for moderate temperatures as platinum, so that it is used for sealing platinum apparatus in making water determinations in chemical analysis of rocks."‡

Tungsten has also been used as an alloy with lead for manufacture of bullets.§

An alloy of tungsten, aluminium, and copper is said to combine lightness with strength, and resistance to oxidation for propellers, automobile parts, &c.||

H. S. Auerbach states that:—

"Although classed among the rare metals, it is surprising to what an extent tungsten is used in the industrial world. In some form or other it is alloyed with practically all the metals. It finds, however, its greatest application as an alloy of steel, to which it imparts many valuable properties. Foreign metallurgists were the first to recognise and take advantage of this fact. . . . .

"The addition of tungsten to steel car-springs increases their stiffness. . . . .

"A bronze powder, much used in decorating, is made by fusing potassium tungstate and tin."¶

* Journ. Iron and Steel Institute, II, 1903, p. 35. † Mineral Resources U. States, U.S. Geol. Survey, 1908, p. 731. ‡ *Ibid.* § Bull. Imp. Inst., VII, No. 3, 1909, p. 294. || *Ibid.* ¶ The Engineering and Mining Journal, LXXXVI, 1908, p. 1147.

III.—ORES OF TUNGSTEN.*

COMMERCIAL—

Wolframite (Fe, Mn) WO_4	... Tungstate of iron and manganese.
Hübnerite $MnWO_4$ ...	... Tungstate of manganese.
Ferberite $FeWO_4$ ...	... Tungstate of iron.
Scheelite $CaWO_4$ ...	... Tungstate of lime.
Cuprotungstite $CuWO_4$ ...	... Tungstate of copper.
Cuproscheelite (Ca, Cu) WO_4	... Tungstate of lime and copper.
Stolzite $PbWO_4$ ...	... Tungstate of lead.
Reinite $FeWO_4$ ...	... Tungstate of iron.

WOLFRAMITE.

Monoclinic. *Crystals* commonly tabular; also prismatic. Often in bladed crystals; also irregular lamellar; coarse, divergent columnar; massive granular, the particles strongly coherent.

Cleavage—Very perfect. Fracture uneven. Brittle.

Hardness = 5–5·5. Specific gravity, 7·2–7·5. Lustre submetallic; metallic-adamantine; resinous.

Colour, dark grayish or brownish black, brownish red, hair-brown; streak nearly black to dark reddish brown; greenish gray. Opaque, or sometimes translucent. Sometimes weakly magnetic.

Before blow-pipe, fuses easily (F = 2·5–3) to a globule, which has a crystalline surface, and is magnetic.

With salt of phosphorus gives a clear, reddish-yellow glass while hot, which is paler on cooling; in R.F. (reducing flame) becomes dark red; on charcoal with tin, if not too saturated, the bead assumes on cooling a green colour, which continued treatment in R.F. changes to reddish-yellow. With soda and nitre on platinum foil fuses to a bluish-green manganate. Decomposed by aqua regia (equal parts nitric and hydrochloric acids.—J.E.C.), with separation of tungstic acid as a yellow powder. Wolframite is sufficiently decomposed by concentrated sulphuric acid, or even hydrochloric acid, to give a colourless solution, which, when treated with metallic zinc, becomes intensely blue, but soon bleaches on dilution.

Dana states that:—

"The most important varieties depend on the proportions of the iron and manganese. Those rich in manganese have specific gravity 7·19–7·54, but generally below 7·25, and the streak is mostly black.

"Those rich in iron have specific gravity 7·2–7·54, and a dark reddish-brown streak, and they are sometimes feebly attractable by the magnet."

"The percentage composition for the pure tungstates, and the compounds in various ratios between them, is as follows:—

WO_3	FeO	MnO	
76·3	23·7	...	= 100
76·4	19·7	3·9	= 100
76·4	18·9	4·7	= 100
76·4	11·9	11·7	= 100
76·5	9·5	14·0	= 100
76·6	...	23·4	= 100

* Dana, Descriptive Mineralogy. 6th Ed., 1892, pp. 982–991

HÜBNERITE.

Monoclinic. Usually in bladed forms, rarely in distinct terminated crystals. Colour brownish red to hair-brown to nearly black. Streak yellowish brown, greenish gray. Often translucent. Chiefly manganese tungstate. Less fusible than wolframite, and gives a strong reaction for manganese.

The original hübnerite was from the Eric and Enterprise veins, in Mammoth district, Nevada, in a vein 3–4 feet wide in argillite, with scheelite, fluorite, and apatite.

This variety has been identified by G. W. Card from near Torrington, where it occurred as "tiny brown blade-like crystals, intimately associated with quartz. An analysis by J. C. H. Mingaye indicated that the mineral contains iron in the proportion of about one part of ferrous oxide to six of manganous oxide."*

An impure hübnerite from Torrington was partially analysed in the Departmental Laboratory in 1903; unfortunately the locality is not specifically defined:—

3578 — / 03	Water	·84
	Tungstic trioxide (WO_3)	34·06
	Manganous oxide (MnO_2)	6·83
	Lead oxide (PbO)	2·41
	Alumina (Al_2O_3)	·80
	Ferrous oxide (FeO)	1·17
	Ferric oxide (Fe_2O_3)	1·70
	†Insoluble in acids (gangue)	50·72
	Lime, ‡magnesia, and undetermined	1·47
		100·00

FERBERITE.

Monoclinic. The original "ferberite" was massive, granular, with some imperfect planes of crystallization. Cleavage perfect. Hardness = 4 – 4·5. Specific gravity = 6·80 Breith.; 7·10 Rg. Lustre imperfectly vitreous, a little submetallic-adamantine. Colour black. Streak brownish black to blackish brown. Opaque.

The Torrington ore (New South Wales) may be classified as "ferberite," as will be seen from analyses on page 70.

SCHEELITE.

Tetragonal; with pyramidal hemihedrism. Contact and penetration—twins. Also reniform with columnar structure; and massive granular. Cleavage: most distinct on octahedral faces. Fracture uneven. Brittle. Hardness = 4·5 – 5. Specific gravity = 5·9 – 6·1. Lustre vitreous, inclining to adamantine. Colour white, yellowish white, pale yellow, brownish, greenish, reddish; sometimes almost orange-yellow. Streak white. Transparent to translucent.

Composition.—Tungsten trioxide, 80·6; lime, 19·4 = 100. Molybdenum is usually present.

Before the blow-pipe in the forceps, fuses at 5 to a semi-transparent glass. Soluble with borax to a transparent glass, which afterwards becomes opaque and crystalline. With salt of phosphorus forms a glass, colourless in outer flame, in inner green when hot, and fine blue when cold; varieties containing

* Records Geol. Survey N.S. Wales, VIII, 1909, p. 155.

† Consisting of clean white quartz and a small quantity of niobic acid. ‡ A good reaction for magnesia.

iron require to be treated on charcoal with tin before the blue colour appears. In hydrochloric or nitric acid decomposed, leaving a yellow powder soluble in ammonia.

Occurs altered to wolframite, by the action of a solution of bicarbonate of iron and manganese, or perhaps mainly through sulphate of iron arising from the decomposition of pyrite; crystals more or less altered to wolframite are common at many localities.

The remaining species are not of commercial value, and need not be specifically dealt with.

O. J. Steinhart* gives in simple language a test for tungsten minerals which identifies them from other minerals which are often mistaken for them—viz., titaniferous iron, magnetite, tantalite, cassiterite, and tourmaline, for wolframite and hübnerite; and barytes for scheelite :—

> "Boil the finely-powdered mineral for twenty or thirty minutes in hydrochloric acid, and after dilution with water drop a piece of zinc, tin, or even iron, into the solution. The appearance of a blue colour, ultimately changing to claret, and finally to brown, caused by the gradual reduction of WO_3 to its intermediate lower oxides, is a pretty certain indication of the presence of tungsten, although molybdenum behaves in a somewhat similar manner."

The name "tungsten," or "tungstein," was originally applied to scheelite. R. A. Hadfield states that :—

> "In 1871, Scheele demonstrated that the mineral found at Biopberg, in Sweden, and called in Sweden 'tung-stein' (heavy stone), on account of its high specific gravity, consisted of calcareous earth and a peculiar 'acid.' Scheele was, therefore, the first to determine the exact composition of the tungsten mineral now known as 'scheelite,' and that it was a combination of lime with tungstic acid."†

The following analyses of concentrates quoted by O. J. Steinhart‡ are of interest for comparison with those locally produced :—

"Wolframite, from the north-western part of Spain :—

Tungsten trioxide (WO_3)	64·13	per cent.
Stannic oxide (SnO_2)	0·68	,,
Manganous oxide (MnO)	6·42	,,
Ferrous oxide (FeO)	10·88	,,
Silica (SiO_2)	7·71	,,
Alumina (Al_2O_3)	5·32	,,
Lime (CaO)	1·21	,,
Magnesia (MgO)	3·16	,,
Chrome oxide (CrO)	0·38	,,

"1. Ferberite concentrates, Clyde Mine, Nederland; 2. Ferberite concentrates, Baker Ranch, Nederland :—

	No. 1.	No. 2.	
Tungsten trioxide (WO_3)	61·15	63·88	per cent.
Silica (SiO_2)	16·10	6·45	,,
Ferrous oxide (FeO)	19·33	20·44	,,
Ferric oxide (Fe_2O_3)	......	0·35	,,
Lime (CaO)	0·38	0·35	,,
Manganous oxide (MnO)	0·51	0·37	,,
Alumina (Al_2O_3)	2·49	2·19	,,
Magnesia (MgO)	0·39	0·50	,,

* The Mineral Industry, XVII, 1908, p. 831.
† Journ. Iron and Steel Institute, II, 1903, p. 23.
‡ The Mineral Industry, XVII, 1908, p. 830.

"Electro-magnetically separated ore, originally associated with tin ore from mines in Cornwall :—

Four Samples.

Tungsten trioxide (WO_3)	60·3	to	72·4	per cent.
Stannic oxide (SnO_2)	0·66	,,	8·75	,,
Insoluble	2·20	,,	4·	,,
Ferric oxide (Fe_2O_3)	2·4	,,	9·4	,,
Ferrous oxide (FeO)	13·5	,,	16·2	,,
Manganous oxide (MnO)	5·2	,,	5·4	,,

"Hübnerite, from Natalie Mine, Silverton, Colorado :—

Tungsten trioxide (WO_3)	70·21	per cent.
Silica (SiO_2)	4·91	,,
Ferrous oxide (FeO)	2·03	,,
Lime (CaO)	0·37	,,
Manganous oxide (MnO)	21·72	,,
Alumina (Al_2O_3)	0·56	,,

"Scheelite, from various countries, shows the following range of composition :—

Tungsten trioxide	69·	to	78·	per cent.
Lime	16·	,,	19·	,,
Iron oxide	0·5	,,	2·2	,,
Manganese oxide	0·18	,,	0·77	,,
Phosphoric acid	0·14	,,	0·2	,,
Silica	2·5	,,	12·5	,,

IV.—CONCENTRATION OF TUNGSTEN ORES.

Scheelite.

All the first-grade concentrates produced at Hillgrove are crushed and concentrated by hand by means of bucking irons or hammers, usually on extemporised tables or flags of granite; and primitive, but effective, jigs on a small scale. The capricious occurrence of scheelite, in small lenses and thin veins, frequently in the stupendous gorge of Baker's Creek, necessitates dressing plants wherever the mineral is obtainable; and the limited output of one given locality offers no inducement for erection of crushing machinery.

For long the "seconds" from spalling and jigging were valueless to the producer; now, however, these can be treated locally at a cost of 15s. per ton. Moreover, the usually associated antimony sulphide forms a second commercial product from the Wilfley tables.

The Writer is indebted to Mr. F. H. Gibson, of the Bull Frog Lode, Hillgrove, for the following sketch of his extemporised jigging plant, which illustrates the local method of hand concentration. Also for the

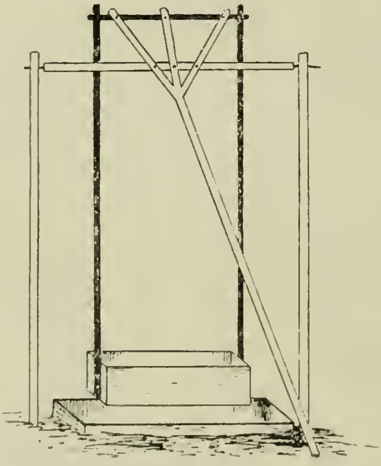

Fig. 1.—Jigging Plant, Bull Frog Lode, Hillgrove.

following dimensions of his compact bucking table:—Height, 3 ft.; width, 3 ft.; length, 6 ft.; divided in centre for two men simultaneously crushing. Estimated that two men can buck and sieve two-thirds of a ton in eight hours with this plant. The bucking hammers are 5 inches square and weigh 6 lb.

The following notes on concentration tests by means of a Huntington mill and Frue vanners at the late Government Metallurgical Works at Clyde (New South Wales), in 1900, may be of interest. The parcels, of which

T. H. Nicholas.

Torrington Ore Company's Battery and Concentration Plant, Bismuth, near Torrington.

Mrs. J. Shannessy.

Rockvale Wolfram Company's Battery and Concentration Plant (under construction).

Tungsten near Torrington.

the following particulars are supplied, were probably the first in the State to be subjected to machine tests :—

Ore containing Scheelite, from Hillgrove; crushed and concentrated at the Government Metallurgical Works, Clyde, New South Wales, in 1900, under the supervision of J. C. H. Mingaye, F.I.C., F.C.S., Analyst and Assayer.

No.	Mineral.	Weight. tons. cwt. qrs. lb.	Assay value. WO_3 %	Concentrates produced. tons. cwt. qrs. lb.	Assay value. WO_3 %	Tailings Assay value. WO_3 %	Remarks.
1	Scheelite	6 16 2 4	13·0	No. 1—0 7 3 16 No. 2—0 10 3 9	64·5 55·5	2·32	Antimony 1·48 %; Gold 1 dwt. 23 grs.; Silver 1 dwt. 18 grs. per ton. No record of tailings assay—books missing
2	,,	5 2 3 5	6·34	0 8 3 26	40·16	?	
3	,,	9 18 2 12	8·81	1 0 1 20	56·15	1·40	Antimony 2·05 %
4	,,	6 2 0 11	2·5	0 4 3 8	48·5	?	Antimony 2·5 %; Gold 1 dwt. 23 grs.; Silver 3 dwt. 22 grs. per ton.

The hand-dressed marketable concentrates run from 70 to 72 per cent. of tungstic oxide. Scheelite is slightly lower in value than wolfram (usually 2s. to 3s. per unit), but contains a higher percentage of tungstic oxide (80·6 to 76·6 in the pure minerals); hence an equal value is attained by dressing to a correspondingly higher grade. Wolfram concentrates usually run from 60 to 70 per cent. tungstic oxide.

The battery of the Eleanora Gold Mine during 1909 was utilized to treat waste heaps of material which had accumulated at the various scheelite mines. About 1,800 tons were crushed, and the mineral concentrated by Wilfley tables; 35 tons of concentrates, valued at £2,775, being obtained, equivalent to 1·9 per cent.*

Before discussing local practice it will be of interest to note that of other countries. Of American concentration, W. L. Fleming states† :—

"Successful wet concentration of tungsten is difficult, although mills claim to save from 70 to 90 per cent. In 1909 the American Smelting and Refining Company made an appropriation for experiments in tungsten ore dressing at the Globe plant, near Denver. The usual basis of quotations on tungsten ores is a grade containing 60 per cent. WO_3, and when the product falls far short of this content, it is difficult to sell even at a reduced quotation. Of late, however, buyers are taking the Colorado product on a 40 per cent. basis, thereby allowing the mills to send a great deal of the quartz which carries slime into the finished product, and avoiding a heavy loss. Wolframite is slightly magnetic, and magnetic concentration has been tried with success in some cases. This process does not apply to scheelite.

"Wet concentration is the means generally employed. In this connection tungsten ores are difficult to work on account of the fact that the minerals are relatively soft and slime badly. In California, a scheelite and quartz ore is treated in a mill containing the following equipment: Blake crusher, 6-foot Huntington mill, and 6-foot Frue vanners. It is

Ann Rep. Dept. Mines N. S. Wales, 1909, p. 58. † The Mineral Industry, XVIII, 1909, pp. 691, 692.

claimed that this process makes less slime than would be generated in crushing with a stamp battery, and in these mills no attempt is made to recover the slime. The operators claim to recover 70 per cent. of the tungsten contents of the ore." . . . . .

"The separation in the Boulder County field, Colorado, is difficult, as the tungsten mineral is there scattered through and intimately mixed in fine particles with the gangue (quartz). At the Wolf Tongue mill the ore passes over a 2-inch grizzly, through a 7 x 10 Blake crusher to a 20-stamp battery (the stamps of which weigh 1,000 lb., and make ninety 6-inch drops per minute), through a 20-mesh long-shot screen, thence by launder to a hydraulic classifier, which makes three products. The coarse goes to two No. 5 Wilfley tables, the middlings to a No. 3 Wilfley, and the slimes to two other No. 3 Wilfleys. Tables Nos. 1 and 2 (the No. 5 tables) make four products: a finished concentrate and a tailing for the slimers. There are five 12-foot Wilfley slimers. The slimes from the five concentrating tables are brought together in a tank and distributed to four of the slimers, each of which makes three products: a finished concentrate, a finishing tailing, and a middling taken from the four last panels. The middling goes to the fifth slimer, where two products are made—a concentrate and a tailing. The mill concentrates 15 into 1, and treats 25 tons in twelve hours."

In local milling of wolfram ore heavy stamps are favored, ranging from 800 to 1,250 lb. per stamp, falling 5 to 8 inches, at the rate of 95 to 110 falls per minute. The heavier stamps (1,000–1,250 lb.) are most in request, the crude ore first passing through breakers.

The discharge screens of the stamper boxes are wire-wove, and uniformly 64 holes to the square inch. Even with these coarse screens, it is found at the Torrington Ore Company's battery that 80 per cent. of the concentrates will pass through 1,600 holes to the inch.

Grinding mills—Krupp's and Huntington—have been installed at Mole Table-land and at Hogue's Creek, near Dundee.

The former consists of a wet-crushing ball-mill, of an estimated capacity of 100 tons per twenty-four hours. The screens are wire-wove, of 144 holes to the square inch.

The Huntington mill has a diameter of 3 ft. 6 in., with screens having 144 holes to the inch.

Concentration is effected with Wilfley, Card, Woodbury, Krupp, and Ferrari's tables, and Frue vanners; concave buddles, and blanket tables or launders.

The buddles are dead or stationary; trailing chains or extemporized brushes are used to form circular riffles, or keep the surface of the sediment even.

At the Rockvale Wolfram Company's plant, in the second unit, the pulp, passing 16 to 25-hole screens in the stamper boxes, will run to a 5-hutch May Bros.' jig; the "spigots" to a five-screen Huntington mill of 64 mesh; the mill pulp from which will be fed to Card tables after passing through a Spitzkasten classifier.

A classifier is also used in connection with the pulp from the Krupp ball-mill at the Torrington Wolfram Proprietary Company's plant.

The Huntington mill plant running in connection with the Glen Eden Mine, Hogue's Creek, near Dundee, embraces a No. 2 Dodge rock-breaker, 3 ft. 6 in. Huntington mill with screens of 144 holes to the square inch, and an Imperial Woodbury table; the seconds being twice run.

Mrs. J. Shannessy.

Tungsten, near Torrington.

Torrington Wolfram Proprietary's Krupp Ball Mill and Concentration Plant.

Mrs. J. Shannessy.

Tungsten near Torrington.

Rockvale Wolfram Company's Hauling Plant, Carters' Section.

It was estimated that about £20,000 was spent in 1910 in erection of treatment plants in connection with the industry.

An analysis of tailings from the Torrington Ore Company's plant is given on page 32. Though, apparently, the tailings appear free from wolfram particles, the analysis shows a little under 1 per cent. to be present.

The Queensland methods of dressing and concentration have, so far, been of a primitive character (see p. 32), but the recent establishment of a modern plant is described in the Queensland *Mining Journal** as follows :—

> "The new mill erected by the Irvinebank Mining Company, at the Mount Carbine wolfram field, about 20 miles from Mount Molloy, commenced continuous crushing on 30th May last. From notes supplied by Mr. S. Horsley, Inspector of Mines, we learn that the new battery occupies an imposing situation on the eastern slope of the hill and facing Manganese Creek. It is capable of treating about 50 tons daily. The plant consists of twin hoppers, rock-breaker, elevator, twin feeding hoppers, self-feeders, and ten head of stamps, the last-named in separable units of five each, for reducing the wolfram-bearing quartz to pulp. The concentration plant is systematically arranged in two exactly similar parts. Each part has at its head a spitzkaste, or classifier, from which the heavier material is sent to three catching jigs and one dressing jig. The lighter material overflows from the classifier to four settlers of varying capacity in succession. The first settler delivers its contents to a Card table, the second and third to Krupp tables, and the fourth to a pair of Luhrigs. The tails of some of these, as well as those from the jigs, are ground in a Wheeler pan and pumped back to the spitzkaste for reconcentration.
>
> "The clean wolfram is fed into a circular drier of a new and improved type, from which it is bagged for transport.
>
> "A tubular boiler of about 40 h.-p. provides ample power through a horizontal engine of even greater capacity. A separate engine drives the rock-breaker and elevator during the day, providing sufficient material for the night-shift; but at night it drives a dynamo, lighting all the works most effectively. The latter has a capacity of 170 c.p. incandescent lights."

Mr. Danvers Power, who recently examined the mine and plant states that the jigs have been discarded in favour of Krupp Tables, the former requiring too much water.

Since concentrating operations began in 25th May, 1911 to 9th September, 3,862 tons of ore, extracted from a lode, varying from a few inches to 9 feet in width, yielded 100 tons 6 cwt. of concentrates dressed up to 73 per cent. of tungstic trioxide.

Magnetic Separation of Wolfram from tin-wolfram concentrates.

Fortunately for the principal wolfram-producing centre, the concentrates are free from value-reducing associates. The Bismuth and Mount Everard Mines contain commercial percentages of bismuth, the former grading to about 6 or 8 per cent. In the others the percentage is usually below commercial grade.

Magnetic separation is, therefore, not a pressing question as in those centres—like Cornwall—where tin and wolfram ores are intimately associated. In the Pulletop, Germanton, Jingellic, and Dora Dora districts, these minerals occur in conjunction, but so far the lodes have not proved of sufficient importance to make the question of separation acute.

* Vol. XII, July 15th, 1911, p. 324.

In Great Britain it is recorded that :—

> "The greater quantity of the tungsten ore at present being produced in this country is obtained in Cornwall as a by-product in tin-working. Deposits which were formerly neglected on account of the difficulty of separating tinstone and wolfram, have now been rendered available by the use of electro-magnetic processes for separating the two minerals. Large heaps of wolframite discarded by earlier workers have been found."*

Scheelite occurs to a very small extent mixed with wolfram in one of the Gulf lodes in the Emmaville Division ; these could be separated if desirable, and in quantity, as the former is unaffected in the electro-magnetic field.

It may be of interest to local holders of mixed tinstone and wolfram—as in the districts mentioned—to quote the following succinct statement of the electro-magnetic separation process in use in Cornwall.

Treatment of Tin, Wolfram, and Copper-bearing Ore in Cornwall.

R. H. Couran, in a paper read before the Scientific Society, Broken Hill, New South Wales,† states :—

> "The method of treatment at the mill taking the ores from the Clitters group is practically the last word in Cornish milling practice. The ore contains cassiterite, wolfram, and copper sulphides. After passing over grizzlies, the ore is broken in Blake-Marsden breakers, and fed by Challenge suspended feeders to a battery of 25–1,100 lb. California stamps, and there crushed through 20-mesh gun-metal wove screens. It is then classified in spitzlutten, giving three spigot products and an overflow. Each of the spigot products is taken to a Buss table, of which there are eight, the middlings from which are reground in a Krupp ball-mill, and afterwards treated on Luhrig vanners. The overflow from the spitzlutten goes to a ten-compartment condensing and classifying spitzkasten. The various spigot products from the spitzskasten are taken to the distributing boxes of double Luhrig vanners, the product of the first three pairs of compartments going to three double vanners, and of the last two to one double vanner. The middlings from these four machines are treated on a fifth one, after some of the water has been eliminated in a spitzkasten. All the tailings pass to an eight-compartment spitzkasten, 40 feet long, where a small quantity of lime is added. A large quantity of water is removed and pumped back to the storage tanks. The tailings pass on to dams, where they are settled, it being illegal to run solids into the neighbouring river.
>
> "The concentrates from the Buss tables, being coarser and of a higher grade than those from the vanners, are roasted separately in a Brunton calciner. They then pass to a Wetherill Magnetic Separator of the c ross belt type, which gives five products. In the first and weakest field, magnetic oxide of iron ; in the second, other oxides of iron, with adhering oxides of copper ; in the third, oxides of iron and wolfram ; in the fourth, wolfram ; the non-magnetic product being oxide of tin and a small proportion of siliceous waste.
>
> "The copper and iron product from the second field is sold to the copper smelters. It contains up to 10 per cent. of copper, and realises a good price, owing to the high percentage of iron oxide present. If

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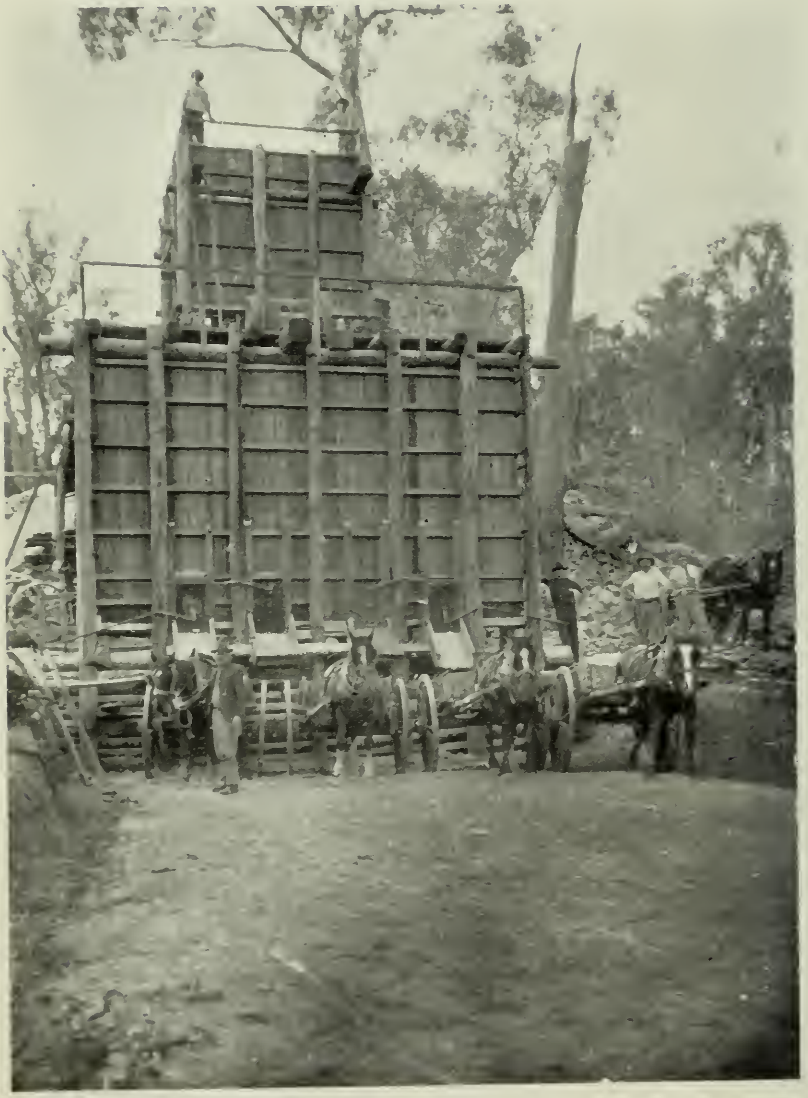
* Bulletin Imperial Institute, VII, No. 2, 1909, p. 171.
† Australian Mining and Engineering Review, I, No. 9, June 5th, 1909, pp. 279–282.

T. H. Nicholas.

Torrington Ore Company's Ore Bin, Fielder's Hill Quarry.

Plate VII.



T. H. Nicholas.

Torrington Ore Company's Ore Bin, Fielder's Hill Quarry.

there is too much tin and wolfram in the first two products, they are crushed dry in a ball mill, and then re-treated. The wolfram products are finished in kieves and sold.

"The vanner concentrates are at present further concentrated after roasting in buddles, then dried in a reverberatory drying furnace, and treated on the magnetic separator, giving similar products to the Buss table concentrates. The preliminary buddling is necessitated by the limited capacity of the magnetic separator. A second machine will probably be installed, when this mill will be avoided.

"The secret of the success of magnetic separation lies in the roasting, it being desirable to produce the greatest possible quantity of the higher oxides of iron, and at the same time eliminate the sulphur and arsenic. If the ore is rich in copper, the iron and copper products of the separator are treated with hot dilute sulphuric acid in a lead-lined vat, and the copper in the resulting solution precipitated on scrap-iron. All the water used in treating the roasted products is passed through precipitation tanks."

The occurrence of wolfram in the Butler tin lode, near Torrington, particularly on the hanging wall, may possibly require magnetic separation in future working.

V.—GENESIS OF TUNGSTEN DEPOSITS.

Mode of Occurrence of Tungsten Ores.

Contrary to general belief, the rarity of tungsten ores refers more to quantity than occurrence. They are found fairly widely disseminated, but usually in extremely small quantities commercially considered. Even when a comparatively large deposit or "bunch" is located, its sudden exhaustion is almost certain, though others are to be expected either below or along the strike of the lode channel. To quote an American authority:—

> "Frequently new finds of tungsten are reported, but the workable deposits are few. A mine when discovered may show quite a bunch of tungsten mineral, but in a few feet of work the shoot may suddenly die out or diminish until the only use for the tungsten is as an encouragement to further prospecting."*

A statement according with Australasian mining experience, especially as regards the rich "bunches" or "bungs" occurring in lodes.

A study of the mode of occurrence of tungsten minerals at the Torrington field, however, offers greater prospect of permanence as regards the more even dissemination of the minerals in the large quartzose masses of that locality. Large quarry faces here reveal a more or less even distribution of the ores through the rock mass, though occasional bunches of pure ore occur, generally in vugs and joints. The average yield of mixed concentrates (wolfram and bismuth ores) usually amounts to about 1 per cent. or less. The possibility of cheap mining, by quarrying, afforded by these large low-grade deposits is another important factor which should go far towards successful exploitation.

America is now the largest producer; Colorado and California contributing the bulk of the output in the order named. Brief notices of the mode of occurrence in these important centres will therefore be of interest.

W. L. Fleming† states that:—

> "The production of Colorado, as heretofore, was entirely from Boulder County, and amounted to 1,100 tons‡ of tungsten concentrates. The producing mines of Boulder County may be divided into two groups: (1) Along a narrow belt about nine miles in length, following Boulder Creek east of Nederland. (2) An area of about one square mile situated about 1½ miles south of Nederland. These two groups comprise the Nederland fields, the most important in the United States both as to extent and richness of the ore. The mineral is locally termed Wolframite, but corresponds in composition and properties to the mineral ferberite. The gangue material is quartz, the vein usually being in a granitic gneiss, mica gneiss, or porphyry."

> "California. Although tungsten occurs at various points in the State, the Atolia region, San Bernardino County, is the only locality where mining is conducted, the entire tungsten production of California in 1909 being made by the Atolia Mining Company.‡

* W. L. Fleming, "The Mineral Industry," XVIII, 1909, p. 690. † The Mineral Industry, 1909, Vol. XVIII, p. 688. ‡ Short tons.—J.E.C.

"The ore in this district is scheelite; it occurs in massive form in bunches and seams in veins which vary from stringers to about 4 feet in width. The vein matter is quartz, altered country rock and calcite; the country rock is granitic. The veins strike easterly and westerly and dip from 40 to 80 degrees north. The Atolia Mining Company is the chief operator in this district. Wolframite has been found in the foothills of the Sierra Nevada Mountains, about 12 miles north of Raymond, Madeira County. The ore occurs in bunches up to 2 or 3 lb. in weight, in a glassy quartz vein, from 4 to 16 inches in width."*

Fleming states that:—

"The tungsten occurs here as scheelite, and wolfram in veins through granite at a distance of from 1 to 2½ miles from a granite contact where copper and silver ores were found and worked about thirty years ago."†

P. H. Carl,‡ states that:—

"For both vanadium and tungsten the production in Colorado in 1910 was larger than ever before; and this is also true of the United States, as Colorado is the principal producer in this country of both of these steel-hardening metals. Tungsten production is now a well-established industry. The ore deposits have been extensively developed and adequate plants provided for handling the ore, so that a dependable supply is assured and the users of the metal are able to make their plans accordingly. As the possible application of tungsten in the manufacture of tool-steel, armor-plate, &c., are such that its use may be indefinitely extended, the market for the metal, now that a regular supply has been provided, has remained stable in spite of the recent depression in the steel industry."

T. L. Walker states:—

"Where intrusive granite comes in contact with slates and schists, quartz or pegmatite veins frequently intersect both the intrusive and the overlying slate schist series. It is now generally agreed that in many instances the cooling and solidifying granite mass contracted, and in the last stages became fissured; the fissures being filled by constituents of the igneous mass which had not yet solidified. This mother liquor filled in the rifts in the rock mass, and on cooling and solidifying gave rise to very coarse granite known as pegmatite. In other instances the granite mass, and the overlying slate series as well, contain irregular veins rich in minerals, containing fluorine, boron, lithium, tin, and tungsten. These are tin ore veins, and at times carry considerable tungsten, in addition. Fissures in the slate-schist appear to have become quartz veins, at times carrying gold or tungsten. Where the mantle of slate or schist overlying the granite mass is not very thick these veins may occur at considerable distance from known outcrops of granite, while the granite may be at no great distance below them. The evidence, therefore, suggests that tungsten deposits found in proximity to granite masses are derived from these constituents of the igneous mass which are expelled towards the close (either as mother liquor or as gases), and find their way into pegmatite masses, irregular tin-wolfram quartz veins in the granite or quartz veins, carrying occasionally gold, or tungsten, or both.§

* The Mineral Industry, 1908, Vol. XVII, p. 827. † *Ibid.*, 1909, Vol. XVIII, p. 688. ‡ Mining Science, LXII, No. 1617, January 26th, 1911, pp. 92-94. § Report on the Tungsten Ores of Canada, Dept. of Mines, Canada, 1909, p. 7.

Queensland being the next largest producer, rather full extracts from local geological reports are given :—

Queensland Tungsten Deposits.

Of their mode of occurrence, B. Dunstan, F.G.S., Government Geologist, states :—

"Regarding the rocks in which wolfram occurs, it was noticed that, while granite is usually the country rock of the wolfram lodes, the mineral also occurs in greisen, felsite, quartz-porphyry, chlorite, schists, slates, and quartzites. In this respect wolfram differs very little from other common minerals, and it would be quite useless to lay down a rule as to the kind of country to which wolfram prospecting should be limited. The most that can be said is to *look for wolfram near granite.*

"The gangue of wolfram is usually quartz, but it also occurs without this mineral in greisen, chlorite, muscovite, biotite, topaz rock, fluor-spar, beryl rock and quartzite (?).

"The deposits are of varying types, consisting of fine veins of quartz, large bodies of quartz, lenticular bodies of quartz, irregular masses of chlorite, quartz, mica, &c., and impregnations of greisen and granite, The irregular deposits have yielded the largest quantities of wolfram, and these have been found in isolated patches or bunches, the invariable pinching-out of which on sinking has given rise to the impression that it is useless searching deeper for similar patches.

"The metallic minerals associated with wolfram are very numerous, bismuth in several forms and molybdenite being the most important from an economic point of view. Other minerals present contain in one form or another, manganese, iron, tin, copper, zinc, lead, uranium, cerium earths, &c.

"Amongst non-metallic minerals, those most commonly associated with wolfram, other than quartz, are topaz and fluor-spar; while tourmaline, beryl, muscovite, and biotite are of frequent occurrence.

"Regarding permanence in depth, *no feature has been observed which in any way indicates wolfram to be limited to shallow deposits.*

"The dressing of the wolfram ore is, on most of the fields, a very simple operation, consisting of hand-picking the stone as it comes from the lode, then burning in kilns, crushing in a spring dolly, sieving by hand, and finally sluicing. The condition in which a lot of the wolfram exists rather favours this treatment, but much of the hand-work could be performed much more economically by mechanical means. At Koorboora a battery is profitably treating stone which contains about 4 per cent. of wolfram."*

Of Wolfram Camp—the centre of the largest production of wolfram in Queensland, and the only place where molybdenite has been profitably mined —W. E. Cameron, B.A., Assistant Government Geologist, states :—

"Wolfram was first discovered here in 1894, when 60 tons were sent away for a return of £670. The mineral was found scattered over the surface in large water-worn lumps and coarse grains, and in a fine condition in the sand of the creeks and watercourses. During 1899, when the price of the mineral was at its highest, 240 tons were sold from the field, of an average value of £38 per ton. A heavy fall in value during the latter part of 1900, and the exhaustion of the more

* Queensland Govt. Mining Journal, VI, 1905, p. 334.

easily obtained surface sheddings from the lodes, led to a reduction of the output to 72 tons for 1901 and 55 tons for 1902, the average price of which was about £18 per ton. As a set-off to this depreciation, the value of molybdenite, which had latterly been found associated with the wolfram in many of the lodes when sunk on below the surface, increased rapidly from £45 a ton in 1900, when the first parcel was sold from the field, to £200 per ton at the end of 1902. The output increased from 11 tons in 1900 to 26 tons in 1901, and 38 tons in 1902.

"*Geology.*—The country at the mines is described by Mr. Cameron as 'granite of a reddish tinge, characterised by a preponderance of siliceous material in the shape of large and abundant grains of quartz, with less abundant red felspar and muscovite mica."

"The wolfram, molybdenite, and metallic bismuth occur associated together in irregular-shaped masses and veins of quartz in the granite. Either wolfram or molybdenite generally predominates in the one lode, the bismuth being scattered through the quartz in smaller patches. None of the lodes occupy well-defined fissures, nor can their outcrops be traced for any distance along the surface. In the case of the more distinctly molybdenite-bearing lodes about 'Jeff's Camp,' these siliceous ore-bearing bodies have been followed down from small outcrops on the surface as irregular pipes of ore, dipping, as a rule, at low angles towards the north. These pipes of siliceous material are surrounded on all sides by granite, the whole of the lode being taken out in the width of an ordinary shaft. There is no sign of any fissure along which the mineral-bearing solutions might have been introduced, or which might be followed in the anticipation of striking other bodies of ore."*

Of the mode of occurrence of tungsten in Portugal—the next largest producer—the Bulletin of the Imperial Institute† contains the following particulars:—

"Some of the most important deposits are situated at Panasqueria, in the province of Beira Baixa, and cover an area of about 1,000 hectares; the deposits are divided into the Panasqueria and Cabeco Pias groups. In the former wolframite occurs, associated with cassiterite, iron oxide and pyrites, mispickel and mica, chiefly in the Cambrian rocks, in quartz veins, which vary in thickness from 4 inches to nearly 2 feet. It is noteworthy that these deposits occur nearly in the centre of a sedimentary deposit, about seven miles from any exposures of igneous rocks; whereas in Spain and Portugal the mineral usually occurs either in igneous rocks or at the contact of them and sedimentary rocks. These beds are nearly horizontal, dipping 5° to 10° to the south."

Origin of the Torrington Wolfram and Bismuth Deposits.—Previous Mention.

Hartwell Conder, M.A., A.R.S.M., writing of the "Wolfram Deposits of New England,"‡ states that:—

"The most prominent rock is the granite which has intruded into the claystones of the Carboniferous period, and appears to be mainly responsible for the elevation of the land. In conjunction with it occurs large masses of quartz-porphyry, hard, and much broken by parallel jointings."

* Queensland Govt. Mining Journal, IV, 1903, p. 350. † Vol. VII, No. 2, 1909, p. 171.
‡ The Mining Journal, Vol. LXXVIII, 1905, pp. 170, 171.

Of the Torrington or Cow Flat wolfram area, Mr. Conder writes:—

"It extends about four miles square, and consists of an elevated plateau composed for the most part of granite. In places, however, the slates or claystones still survive, and it is at the contact of these two rocks that most of the discoveries so far have been made. As the road going north traverses the country, it passes over a series of small ridges rising up some 30 or 40 feet above the rest of the land, and marked by outcrops of barren rock. On nearer examination this rock proves to be closely related to the granite, but so altered by a process of silicification as to be hardly recognised as such. The main granite massif of the district is composed of a black mica variety and about equal parts of felspar and quartz. In these outcrops the mica and felspar have disappeared, and a hard siliceous body remains, for which the Writer can find no adequate name, but merely describes as quartzose rock."

"A marked feature of these formations is that they appear invariably to occur in conjunction with the slate. In some cases they present true contact bodies, with granite on one side and slate on the other. In other cases the quartzose rock is bordered on all sides by the slate, which is penetrated also by radiating quartz lodes.

"It would seem that the outcrops are tongues of igneous rock thrust up into the surrounding slate, and whatever their nature at first, by their position they would probably become outlets for vapours and solutions from the main body, and be largely metamorphosed by these. In some cases, from the homogeneous nature of the rock, the metamorphic action seems to have been carried to its farthest limit. In other instances the rock still retains a granular structure, and might even be mistaken for a quartzite were not the gradations into the surrounding rock readily traced.

"Similarly, the contact between the granite and the slate represents a plane of weakness; and here we find instances where the gradation is most distinct, black mica granite merging into a rock where the crystals of the felspar are decayed away and partly filled with silica; this passes into a solid quartzose rock with no felspar, and merely greenish stains of iron silicate in places. Beyond this comes the indurated claystone with quartz leaders running through it. . . . .

"As accessories to the metamorphic action, we have the economic minerals wolfram and bismuthite, or bismuth carbonate. The wolfram is by far the most plentiful, and occurs both in crystals or patches in the rock, and in small crystals disseminated through it.

"The large outcrops themselves are not sufficiently rich to prove payable; in parts the wolfram occurs permeating irregular patches, which are of good value, but the difficulty and hard work involved in tracing these patches are so great that *en bloc* the stone is not remunerative. It is, however, usually penetrated by veins of quartz from 3 to 12 inches wide, and these veins frequently are enriched to such an extent that they have proved highly profitable to small working parties; but here again the course and dip of the veins is so irregular, and they pinch out so frequently into the quartzose rock, that it would be extremely difficult to work them profitably on a large scale. There are, however, modifications of these larger formations that have proved very profitable.

"The first of these consists of pegmatite dykes associated with the quartzose rock. On one property (Torrington Ore Company's Bismuth Mine.—J.E.C.) a dyke of this nature, with large black mica and felspar crystals, crosses the strike of the siliceous outcrop at a small angle, and dips irregularly towards the slate contact at about 45 degrees.

"In parts it is 12 feet wide, and so far the workings have penetrated about 75 feet, the ore yielding 8 per cent. wolfram and good bismuth values. Fluor-spar, monazite, and beryl also occur. Some of the wolfram slugs are of great size, a lump of pure wolfram, weighing 300 lb., having been taken out.

"Again, in places the slate has been fissured, and a true lode formation is seen. The lode may be either of quartzose nature, apparently an altered granitic dyke, when the wolfram is usually disseminated through it; or composed of crystalline quartz, when the wolfram is generally in large crystals. A very good instance is that of a narrow vein of quartz about 6 inches wide; this split and formed a vugh about 12 inches wide and 20 feet high, lined with quartz crystals. Clayey quartz leaders branched out into the slate, and the whole carried throughout large masses of wolfram, some over 30 lb. in weight.

"Lodes in the granite are also met with. In most cases there is an alteration to greisen along a certain line, and through the greisen runs a lode of quartz carrying wolfram."

E. C. Andrews, B.A., Geological Surveyor, who watched the development of mining operations at Torrington for a considerable period, has contributed two papers,* embodying his views of the genesis of the wolfram and bismuth deposits; and illustrated them by numerous sections of small areas in the Torrington Ore Company's Bismuth Mine, which he believed threw light on his view of the mode of origin of the ore deposit; and on which he based his conclusions regarding the Torrington wolfram occurrences.

Mr. Andrews' views are briefly stated in the following deductions:—

"It appears legitimate to infer that the early Mesozoic coarse acid massif, in 'stoping' its way upward, caused a huge block of the slate and conglomerate roof to founder and sink a considerable distance into its mass; and that between the engulphing and engulphed masses a strong interaction was set up, during which highly hydrated and gaseous granitic secretions were forced along the numerous joints traversing the foundered block. These joints, as a rule, appear to have been very narrow, but the intensely heated gases and water attacked and altered the slates on both sides of the joints to hard granular quartz ('quartzite'). These 'quartzites' were then themselves partly altered to masses of sericite, which, in turn, became modified either to glassy quartz, massive felspar, biotite, or coarse pegmatite, with or without fluor-spar, monazite, beryls, &c."†

The illustrations accompanying the above papers are stated to show, *inter alia*:—

1. Gradual change from slate to cairngorm and "quartzite."
2. Passage of slate to hard granular quartz, and this in turn to brittle glassy quartz, with development of sericite and wolfram.

* Records Geol. Survey N. S. Wales, VIII, Pt. IV and V, 1907. † *Ibid.*, Pt. V, p. 249.

3. Alteration of country (? slate.—J.E.C.) with development of massive white felspar, beryls, fluor-spar, and biotite.
4. Gradual passage of slate to banded compact granular quartz, with further change to pegmatite, associated with wolfram and sericite.
5. Dark and much silicified slate, showing flakes of mica, altering into quartz.
6. Mostly biotite } Phases of slate alteration.
7. Pegmatite }

The results of the whole series of observations are regarded as delineating :—

(1) "Along the joints the slate and conglomerate country is usually altered to compact granular quartz ('quartzite').

(2) "Along joint intersections and the more central portions of the replacements, the minerals developed are usually glassy quartz, massive felspar, pegmatite, sericite with granular quartz, with smaller admixtures of crystalline biotite, fluor-spar, beryls, &c. In the latter occur the best values of wolfram and bismuth."*

In April, 1911, Mr. Andrews, after discussion with the Writer, and examination of recently obtained contact specimens and sections, supplied the following statement for publication in this work :—

"From later evidence obtained by Mr. J. E. Carne, in the nature of sharp contacts between the so-called 'quartzite' (and associated pegmatites) and the sedimentary rocks in the Bismuth, Fielder's Hill, Rockvale, and Oakleigh Mines, it would be better to consider these quartzose masses as actual 'end results' of the granitic differentiation, and not as alterations of the slate.

"The association of sericite in these masses; the peculiar subcircular shape (of the outcrops.—J.E.C.) of such masses as Fielder's Hill, and a comparison of them with the secondary mica gold pipes at Timbarra, had led me formerly to consider the 'quartzites' as being 'more of a compromise between the advance agents of the rising solutions and the country, while the pegmatites and fluor-spar appear to approximate more to the typical composition of the invading solutions.

"This question of origin does not affect the economic question raised in that report in which it was stated that the wolfram ores 'will be found to be distributed along—or near—the whole three dimensional contacts with the slate derelict (or roof) with the granite.'"

C. Bogenrieder, A.I.R.S.M. (Loben), in a paper on "Wolfram Ores, Occurrence and Uses," published in the *Australian Mining Standard*† on 16th December, 1908, describes the geology and mode of occurrence of the Torrington wolfram deposits as follows :—

"The greater part of this area, the Mole Tableland, is of Palæozoic age, with Permian relationships, and consisting of coarse-grained intrusive granite, metamorphosed in a greater or less degree. The character of the granite varies greatly; every variety of the granite is more or less silicified (greisen), quartz and chlorite traverse the granite massif very irregularly. In the altered zone (greisen) the lodes contain only finely-disseminated tungsten ore, and there are also rich veinlets and pockets filled with high-grade ore. Other minerals, such as native bismuth, molybdenite, cassiterite, monazite, occur in the quartz lodes,

* Records Geol. Survey N. S. Wales, 1907, VIII, Pt. V, pp. 244-248. † Vols. XL and XLII, 1908-1909.

and mostly at their contact with euritic granite. Thus the wolfram ores of the New England district occur in three formations :—

"(1) Crystalline rocks—consisting of muscovite, biotite, quartz, felspar.

(2) Euritic granite—consisting of quartz, felspar, and hornblende.

(3) Alluvium overlying Silurian claystone—consisting often of chlorite, in which the wolfram is embedded, together with beautiful loose crystals of beryl, monazite, topaz, and quartz (Heffernan's claim)."

Careful study of the mode of occurrence of the Mole Tableland lode-rock, locally designated "quartzite," and of the associated sedimentary rock known in the district as "trap," compels the Writer to conclusions distinctly antagonistic to the "absorption" and "alteration" theory advanced.*

Extensive quarries and other workings expose numerous instructive contacts of the four classes of rocks represented in the field—viz., granite, quartzose ore-rock, pegmatite, and sedimentary.

The intrusion of the quartzose and pegmatitic ore-rocks, both in the granite and in the sedimentary rocks, is conclusively established by the evidence of the contacts.

In most instances the lines of division between the intruded and invaded rocks are sudden and distinct. Wherever signs of alteration are visible they are confined to superficial margins, and usually take the form of secondary mica on the surface of the sedimentary rocks or partial metamorphism of the contact area.

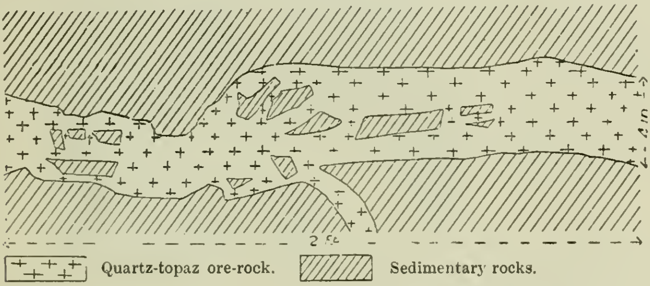


Fig. 2.—Intrusive Contact. Fielder's Hill Quarry. M.L. 325, Parish Rock Vale, County Clive.

Usually, however, the boundaries of the latter have been broken and invaded by the intrusive ore-rock ; fragments of the sedimentaries engulphed in the igneous rock retain sharp angular outlines, notwithstanding partial alteration. Huge blocks, moreover, have been similarly engulphed without marked alteration, as will be seen from the accompanying sections and photographs. Only where the invaded rock is shattered and intruded by tongues and veins of the igneous rock is any appreciable effect noticeable.

It is indeed remarkable, considering the extent of disturbance, how little the sedimentary rocks have been affected. Even in close contact—as at Fielder's Hill—conglomerate pebbles are readily detachable from the sandy matrix in

* E. C. Andrews, Records Geol. Survey N. S. Wales, 1907, VIII, Pt. 3, pp. 239-251.

which they are embedded; whilst sandstones, beyond harshness and friability, betray no marked evidence of metamorphism even near the actual contacts.

Where there is evidence of contact metamorphism, the altered selvage is altogether distinct, and sharply marked off, from the coarse semi-granular quartzose ore-rock. Moreover, the latter intrudes granite at considerable distances from the sedimentaries, where absorption and alteration of the latter is not involved.

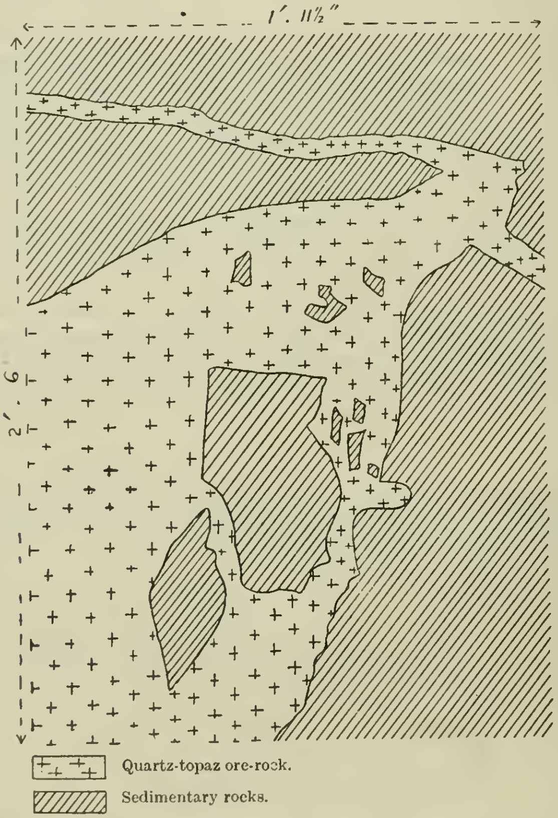


FIG 3.—Intrusive Junction of Ore-rock at Fielder's Hill Quarry.
M.L. 325, Parish Rock Vale, County Clive.

Wherever the Writer has observed silicic replacement of sedimentary rocks, the result has invariably been horny or colloidal, with retention of original cleavage and bedding planes; and not pellucid and coarsely granular as in the Mole Tableland rock.

The possibility of alteration of a slate (or claystone) through sericite and brittle quartz, to cairngorm and finally pegmatite, as postulated, has been subjected to critical investigation in the field, and to the light of scientific literature; the consensus of opinion being against such a transformation.

Van Hise, in his monumental work on "Metamorphism," states that :—

"Pegmatization has been variously explained as the result of true igneous injection, of aqueo-igneous action, and of water impregnation or cementation. Brögger has strongly enforced the idea that many pegmatite veins are true igneous injections. In support of this idea he cites undoubted frequent association of pegmatitic veins with intrusive masses of acid rock, the fact that many of the pegmatitic veins behave like other eruptives, and that their structure is that of igneous rocks."*

Van Hise's own view is given on page 723, after quoting G. H. Williams opinion in support of igneous origin:—

"It seems to me that to explain adequately all the facts of pegmatization described in various regions of the world, we must conclude that all three processes have been at work—in some cases igneous injection, in some cases aqueo-igneous action, in other cases pure water cementation, and in still other cases combinations of two or all of these processes. It is further believed that there is no sharp separation between these processes, but that, on the contrary, they are all gradations between the three. That is, it is thought highly probable that, under sufficient pressure and at a high temperature, there are all gradations between heated waters containing mineral material in solution and magma containing water in solution. In other words, under proper conditions water and liquid rock are miscible in all proportions."†

"In summary, pegmatization, when it occurs on a great scale, usually is found in connection with great intrusive masses in which there have been long-continued composite intrusions. No great batholith is the result of a single simple intrusion. The introduction of such masses went on irregularly through a very long time. Pegmatitic masses are not the result of a distinct epoch of eruption, but usually are produced in connection with the closing phases of igneous activity. The pegmatites very frequently cut the igneous rocks intruded at an earlier stage of the igneous epoch. After the main masses of igneous rock have crystallized they continue to contract as they cool, and are thereby fractured. This occurs while they are still very hot, and gives ready access to the pegmatizing material."†

Re fusion and recrystallization Van Hise states :—‡

"The only way which I can suggest to show fusion and recrystallization on a large scale is to prove that the rock supposed to be fused and recrystallized possesses the chemical composition of the rock from which it is believed to have been derived. For instance, a fused and recrystallized shale should possess the textures and structures of an igneous rock, but the essential chemical composition of a sedimentary rock.

"There can be no question that fusion of fragments included with igneous rocks does take place, very numerous inclusions which are found adjacent to great batholiths show various stages of absorption. Frequently the partly absorbed residual fragments are profoundly metamorphosed, being perhaps, completely recrystallized, and frequently greatly changed in chemical composition from that of the parent rock."

"It may well be doubted whether the excess of heat in a molten magma, beyond that required to keep it liquid. is sufficient to perform' the vast amount of work required for liquefaction of a great mass of

* U. States Geol. Survey, 1904, p. 721. † *Ibid.*, p. 727. ‡ *Ibid.*, p. 730.

solidified rock. Work has to be done in fusing the material, and work must be done in expanding the material. Besides raising the temperature to the fusion point, all the latent heat of fusion must be supplied. The heat required for the process of fusion of rocks in a furnace is very great. Ordinarily a magma has a temperature only slightly in excess of that required to hold it in liquid form. Therefore, that it could furnish a sufficient amount of heat to liquefy immense masses of solid rocks seems highly improbable."*

"If any considerable mass of solidified rock were fused as a result of contact with igneous rocks, it is natural to suppose that for a zone of variable width the two would become mixed, and thus there would be a gradation in chemical composition between the fused rock and a normal magma."

J. P. Iddings states :—

"Evidences of absorption by the igneous magma of material from adjoining rocks are very slight, even in cases where these rocks have been profoundly affected by the intruded magma. There appears in most cases to have been almost no solution and diffusion of material from the adjacent rocks ; the chemical composition of the igneous rock is not different where it is in contact with quartzite, limestone, or silicate rocks of various kinds. In many cases of fine-grained intrusive, quartzose igneous rocks there is no evidence of appreciable reaction between the igneous rock and the invaded rock, even where this is a carbonate. It commonly happens that blocks, or fragments, of rocks are enclosed in molten magma without exhibiting evidences of solutional reaction between the magma and enclosed blocks. The contact surface between them is frequently distinctly recognisable, there being no evidence of blending. Few statements as to signs of solution and diffusion of rock by igneous magmas have been substantiated by chemical evidence of a change in the intrusive igneous magma, due to such a reaction.

"It appears from a study of intruded igneous rocks that they were not sufficiently heated to melt, or dissolve, invaded rocks to any appreciable, or at most to any considerable extent. In many cases the temperature was near that of saturation for some of the components, and often near the point of solidification of the whole magma, as shown by the minuteness of the crystals formed and by the absence of metamorphism in the adjoining rocks. And in some cases of profound metamorphism of the surrounding rocks it appears to have been escaping gases that effected the change, the igneous rock exhibiting no signs of reaction."†

The outlier of claystones, sandstones, and conglomerates in the Parish of Rock Vale, County Clive, with which the Mole Tableland, or Torrington, wolfram and bismuth deposits are so intimately associated, has been provisionally classed as Permo-Carboniferous (Lower Marine) to agree with strata at Swamp Oak Creek, and near Rocky Creek, where palæontological evidence has been obtained in favour of this classification. So far, none has been obtained from the outlier, though conglomerates are well developed, and with these the fossiliferous beds of the localities mentioned are associated.

The sedimentary rocks have been intruded by the granite, and both by the latest phase of granitic intrusion—the quartzose ore rock, in the form of dykes, sills, and bosses.

* U. States Geol. Survey, 1904, p. 731. † Igneous Rocks, Vol. I, 1909, p. 282.

Considerable difficulty is experienced—as pointed out by Conder—in establishing a name for the Torrington ore-rock, which will denote its composition, and yet imply its origin.

The local term "quartzite" conveys a good idea of its macroscopical structure, but gives an erroneous impression of origin.

"Quartz-rock" denotes its principal composition, but is apt to conflict with the ordinary vein-filling quartz. Its igneous and intrusive origin is established by fractured contacts, and confirmed by miarolitic vugs lined with quartz, and occasional felspar crystals.

J. Lomas* and A. Harker† discuss quartz as an igneous rock. The former states that:—

> "There is *a priori* no reason why quartz should not exist as an igneous rock. Given a magma with a limited amount of bases, combinations would go on until the silica had united with all the bases available, and then a residuum would be left which on consolidation would be pure quartz."‡

Harker states:—

> "There can be no doubt that, on the fringe of a granite intrusion and its apophyses, we sometimes find a gradual transition from normal granite through various rocks which may be termed pegmatite, greisen, &c., to pure vein-quartz."

He, however, considered that:—

> "Closer inquiry was necessary before we can be warranted in regarding such quartz veins as igneous rocks in the ordinary sense. There are many indications, both from the geological and from the petrographical side, that the more siliceous products in question, and especially the pure quartz-veins, belong at most to the waning stage of igneous activity, when the temperature had fallen, and the agency of water had become a more important factor."§

Both these authorities were, however, discussing admittedly homogeneous quartz-veins of moderate width, that in no way correspond to the massive outcrops of quartzose-rock forming the Mole Tableland wolfram and bismuth lodes. As before stated, the intrusive character of the latter is well established, and it is probable that further investigation, as mining development proceeds, will reveal a gradual approximation to an aplitic constitution. The presence of a pipe of pure kaolin in the massive quartzose outcrop at Fielder's Hill is very significant in this connection, and may represent felspar originally disseminated through the mass.

The structure of the ore-rock resembles a semi-granular aggregate of granite quartz, and not homogeneous vein-quartz.

J. E. Spurr,|| describing a class of quartz-alkali felspar rocks, which he named "Alaskites," states that:—

> "These rocks are sometimes fine-grained, or may be coarse, like granites, but have a nearly uniform structure and composition. In the Alaskite series the change is continued by a relative increase in amount of quartz and decrease of felspar. One remarkable phase studied is a porphyritic dyke rock whose groundmass consists almost entirely of quartz in small interlocking grains, giving both in the hand specimen and under the microscope the exact appearance of a quartzite."

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* Geol. Mag., New Series, X (4), 1903, pp. 34-36. † *Ibid.*, p. 95. ‡ *Ibid.*, p. 36. § *Ibid.*, p. 95.
|| Trans. Inst. of Mining Engineers, XXXIII, 1903, p. 310.

The composition of the Fielder's Hill kaolin is shown in the following analysis by W. A. Greig :—

Water (100° C)	1·80	
Water above 100° C	10·05	
Silica	55·26	
Alumina	30·82	
Ferric oxide	0·90	
Ferrous oxide	trace	
Lime	0·32	
Magnesia	0·26	
Potash	0·38	
Soda	0.32	
Manganous oxide	trace (under 0·02)	
Titanium oxide	absent	
Phosphoric anhydride	0·06	
Sulphur trioxide	absent	(Spectroscopic reaction only)
Strontia	present	
Lithia	present	
	100·17	

No soluble chlorides or sulphates present.

Since the above was written, the Torrington associated rocks have been submitted to careful petrological examination by G. W. Card, A.R.S.M., Curator and Mineralogist, whose determinations set beyond doubt the intrusive (granitic) origin of the ore-rock. The following notes are the results of his observations :—

[**8245**] Granite (Alaskite); Carter's Wolfram Lease.

"Gray. Porphyritic, with phenocrysts of quartz and creamy felspar up to 15 mm. in length. The groundmass is flecked with black mica.

Under the microscope, the felspar comprises orthoclase and albite, and a combination of the two gives rise to the variety perthite. There is a very little black mica, and nests of secondary mica. This latter has developed in the felspar to some extent.

[**8253**] Granite. Torrington Bismuth Mine. (See below.)

Felspar.

"A special examination was made by the Analyst of felspar from the Torrington Bismuth Mine. This has a specific gravity of 2·542, while the potash and soda contents are $11\frac{1}{2}$ and $2\frac{1}{2}$ respectively ; it is therefore orthoclase.

Mica.

"Associated with the Torrington wolfram deposits is a dark mica which has hitherto been regarded as biotite, on account of certain optical properties. A suspicion that it was in reality a lithium-bearing mica was confirmed (by H. P. White) by a spectroscopic examination of specimens from the following localities :—Cow Flat, Wild Kate, Bismuth Mine, Heffernan's, and Fielder's Hill. A chemical examination will be made of the large flakes found at Smith's Mica Lode, Black Swamp, and in the meantime Mr. White has shown that it is a lithium-bearing variety very rich in iron. The classification of the Micas does not rest on a very satisfactory basis. The nearest analogue seems at present to be the variety found in the Erzzeburg Tin-field, and known as Rabenglimmer—raven mica.

It should be noted that the mica occurring in the fine-grained dark-coloured, and coarser grained light-coloured rocks respectively appears to be one and the same variety.

Topaz-bearing rocks.

"The specimens examined are from Fielder's Hill and from the Torrington Bismuth Mine. The phenomena from the two districts are similar.

Fielder's Hill.

"[**15360**] (M) to the eye is a quartz rock, but under the microscope much topaz is seen, and here and there a little orthoclase.

"[**8248–9**] are obscurely banded, fine-grained quartzite-like rocks. These, under the microscope, consist of much topaz, with quartz.

"[**8250**] is an ash-coloured finely granular rock, traversed in all directions by veins of a coarser granitic-looking rock, much lighter in colour.

The former can be partly studied with the pocket lens. Under the microscope, it consists of dark mica and quartz, with some topaz in places. The constituents are evenly granular, and uniformly distributed. The average grain size is about 0·1 mm. The latter consists of the same minerals in different proportions, mica being subordinate and topaz much more important.

While it would seem as if the coarser rock intrudes the finer, there are some appearances which point the other way.

[**8251**] Generally similar to 8250.

"Bismuth Mine.

"[**15365**] (M).—A vein of pegmatite, fringed with dark lithia mica-traverses a fine-grained rock similar to those described from Fielder's Hill.

"[**8247**] A dark, sedimentary-like rock, very fine-grained. Under the microscope it is difficult to make out, but would appear to closely resemble the fine-grained dark rocks above described.

"[**8253**] A dark, fine-grained quartz-topaz mica rock, traversed by veins of topaz-bearing granite. Bands in the former are distinctly faulted by the latter, the relative ages being thus clearly established. The older rock contains much dark mica, and the constituents can be discerned by the unaided eye. The invading granite is an even-grained admixture of quartz and white felspar, while smaller amounts of a dark mica and a silvery form are also present. Under the microscope, topaz is seen. The felspar is principally cloudy orthoclase, but small clear crystals of a rather basic plagioclase occur. The silvery mica appears to be sericite, but it is not very evident whether it (and topaz) is replacing felspar or not. It is not at present known whether the dark mica is a lithium variety.

"Origin of the Rock.

"That the lighter-coloured, coarser rocks are, more or less, altered forms of intrusive granite seems reasonably certain. Where felspar has been completely destroyed, either a quartz-topaz-rock or a quartz-lithia-mica-topaz rock remains, which is quite analagous with greisen, but for which no particular name has as yet been applied. Topaz-greisen would, in some respects, seem suitable. The origin of the dark, fine-grained rock is uncertain, the microscope affording no direct evidence. That it may be a sedimentary rock, completely altered by metasomatism, seems possible."

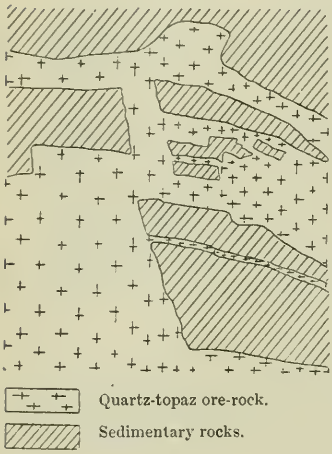

FIG. 4.—Section of intrusive contact in "Bismuth" Mine, Torrington. Scale about 2 ft. to an inch.

(The latter surmise is in accord with field evidence, the samples all being from contacts.—J.E.C.)

No evidence is forthcoming of deep foundering of the Permo-Carboniferous outlier in the underlying granite, the reverse being the case, the igneous intrusives being forced up into the sedimentaries in the form of bosses, dykes, and sills.

The intruded sedimentaries of the Mole Tableland occur simply as a mass isolated by denudation from the extensive development of the series along the Beardy and Mole River systems. Wherever their margins are in contact with the acid granite or with extensive porphyries in these localities, the same conditions occur, the division lines being sudden and distinct, even where tongues and thin dykes of the intruding granitic rocks penetrate the sedimentaries.

Such contacts are open for study in many places, and are all against the absorption and alteration theory.

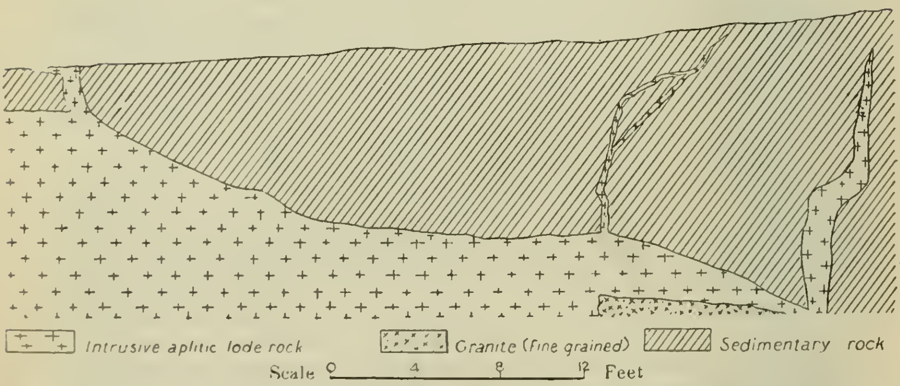

FIG. 5.—Section in entrance to Carter's Cut. M.L. 70, Parish Bates, County Clive. Torrington Wolfram Proprietary, Ltd., showing intrusive contact.

Of the genesis of the Hillgrove lodes, in which scheelite occurs, E. C. Andrews states that:—

"In the gneissic granite, on which the town of Hillgrove stands, and near its contact with the spotted slates of the locality, numerous veins of scheelite are known to occur. At times the occurrences appear to be true fissure veins, at others they appear to fill contraction fissures in the granite. Dykes of varying composition and texture at times accompanying the scheelite. The reefs, as shown by a study of these dykes, appear to be referable to at least two periods of vein formation, one set originating not long after the consolidation of the upper granite mass, another forming a secretion from a magma producing a later set of dykes. These dykes, it may be added, appear to have determined the greater number of the auriferous reefs at Hillgrove."*

"This mineral occurs in true fissures, both in granite and slate. Dykes of varying degrees of basicity (chiefly intermediate), often accompany the reefs. The reefs apparently owe their existence to the action of this dyke series, which cuts alike both the granite porphyry and the diorite of the district.

"The igneous rocks appear either—

1. To have caused vigorous circulation of water by heating through the older granite porphyry, thereby causing segregation of the contained scheelite;
2. Or to have caused a hydrated excretion to be given off by a deeply-seated magma, whose earlier differentiations resulted in the dyke formations themselves. This hydrated excretion would contain the scheelite.†

The Hillgrove granite, in which the scheelite lodes occur, has been analysed by J. C. H. Mingaye, with the following results :—

	Weight percentage.	Molecular Ratio.
Silica ($Si\ O_2$)	69·55	1.159
Alumina (Al_2O_3)	14·16	0·139
Ferric oxide (Fe_2O_3)	0·60	0·004
Ferrous oxide (FeO)	3·33	0·046
Magnesia (MgO)	1·45	0·036
Lime (CaO)	2·20	0·039
Soda (Na_2O)	3·14	0·051
Potash (K_2O)	4·09	0·044
Water (H_2O 100C°)	0·20	
,, (H_2O 100°C+)	0·30	
Carbonic acid (CO_2)	0·04	
Titanic acid (TiO_2)	0·54	0·007
Zirconium oxide (ZrO_2)	none	
Phosphoric acid (P_2O_5)	0·12	0·001
Sulphuric acid (SO_3)	0·11	
Chlorine (Cl)	none	
Fluorine (F)	none	
Sulphur S (FeS_2)	none	
Chromium sesquioxide (Cr_2O_3)	trace	
Nickel and cobalt oxide (NiO, CoO)	none	
Cuprous oxide (Cu O)	trace	
Manganous oxide (MnO)	0·23	0·003
Barium oxide (BaO)	0·07	
Strontium oxide (SrO)	trace	
Lithium oxide (Li_2O)	none	
Vanadic oxide (V_2O_5)	none	
	100·13	

Specific gravity, 2·658

* Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 142.
† Ann. Rept. Dept. Mines N. S. Wales, 1905, pp. 150, 151.

G. W. Card determined the norm as follows :—

Quartz	26·6
Corundum	0·8
Orthoclase	24·5
Albite	26·7
Anorthite	10·0
Hypersthene	8·0
Magnetite	0·9
Ilmenite	1·1
Apatite	0·3

"This rock would be classified by the Quantitative System as 1, 4, 2, 3, under the magmatic name of Toscanose."*

W. A. Longbottom, A.S.A.S.M., in a paper entitled "Scheelite Mining—Occurrence and Treatment in New South Wales,"† states that :—

"The scheelite belt in the Hillgrove district has been proved over an area of approximately four miles in length by two miles in width, though the actual value of the mineralized belt is very patchy. The ore is found in true fissure lode formation, averaging anything from 6 inches to 1½ inches in width ; and where the lodes are cut by cross courses or faulted, the scheelite is often found in a crystallized condition at right angles, and in lenticular masses lying along the wall, and these patches are generally very rich." . . . .

"It is rather curious, but well worth noting, that in practically every case of faulting met with the lode is ultimately picked up again to the *right* and *above* its position before being intersected, presuming the scene of the alteration to be faced by the observer.

"Another coincidence worth remarking on is that the scheelite country seems to have located itself on either side of the gold reefs, and runs as nearly as possible parallel with them, and this fact may have its significance."

* Records Geol. Survey N. S. Wales 1907, VIII, Pt. 3, p. 20.
† The Mining and Engineering Review, Feb. 6th, 1911, Vol. III, No. 29, pp. 199, 200.

VI.—PERMANENCE OF TUNGSTEN DEPOSITS

The persistence of tungsten deposits in depth, and the maintenance of values, are naturally vital questions confronting investors, particularly at Torrington, where the deposits are large and capable of being worked by quarrying. Before recording local indications of permanence, it will be well to study the rather scanty literature of tungsten occurrences in other countries bearing on the subject.

Victor G. Hills,* describing those of Boulder County, Colorado, U. States, states :—

> "The veins of this district are numerous, but small and irregular, and usually cannot be traced far. The tungsten ore deposits have been described as 'bunchy.' This is true, generally speaking, and conforms to the description of tungsten veins all over the world." . . . .
>
> "In the deepest workings which I have seen the ore shows no sign of impoverishment. In fact, the principal vein of the Colorado Tungsten Corporation, at 320 feet down on the dip of the vein (230 feet vertically below the surface), shows a better ore-shoot than ever before. This was, until recently, the deepest mine in the district, and probably the deepest exclusive tungsten mine in the world. The Conger Mine, located on a parallel vein 400 feet distant, is now down 360 feet deep and working, and it is reported to have the best ore-body that it has ever shown."

Hartwell Conder, in his description of the Torrington deposits of New South Wales, remarks that :—

> "The permanence of the ore in depth is another question. So far no workings here have gone below 100 feet, at which depth wolfram in moderate quantity was met with, but the Writer's own impression is that secondary enrichment has taken place in the shallow depth."†

E. C. Andrews states :—

> "The method of formation for these Mole Tableland wolfram deposits suggests an interesting problem in the permanence or otherwise of these ore masses at lower levels. They should, certainly, occur all round the contact of the granite (the euritic granite) and the slate mass." . . .
>
> "There is no reason to doubt that certain of the Cow Flat ore deposits will continue as quartz deposits to considerable depths. Whether the average tenor in value, as proved near the surface, will be maintained, the Writer has grave doubts, since wolfram and bismuth are doubtless amenable to the laws of secondary concentration, much as are silver, gold, and copper. In that case the richest values may be expected to occur in the upper two hundred feet."‡

Mr. Conder noted as strange the absence of sulphide minerals, even bismuthinite, but they were hardly to be expected at such a shallow depth. The deepest workings (presumably at the Bismuth Mine) then not exceeding 100 feet, and this at a low angle. Even at the present depth of 350 feet the vertical level of the face is only about 150 feet below the surface.

Moreover, sulphide minerals do occur of bismuth, cobalt, and molybdenum ; but the first-mentioned is more commonly in the form of native bismuth.

The Writer is disinclined to agree with the views expressed as to secondary enrichment of the wolfram, preferring to regard it as essentially a primary mineral at Torrington.

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* Proc. Colorado Sci. Soc., IX, 1909, p. 138. † The Mining Journal, LXXVIII, 1905, pp. 170, 171.
‡ Records Geol. Survey N. S. Wales, 1905-9, VIII, Pt. 3, pp. 250, 251.

So far as his observation has extended, the common alteration of wolfram to tungstic, or wolfram, ochre—a soft, earthy, greenish, grey or yellow substance—(WO_3) is very superficial indeed; and though soluble in caustic alkalies, is insoluble in acids, which are more likely accompaniments of vadose circulation in an area of acid rocks. This insoluble product (in acids) is therefore unlikely to have caused enrichment at slightly lower levels, nor is there any evidence of such in any of the workings so far opened. Rich bunches of wolfram occur at all levels, in some cases apparently isolated in the ore-rock, but usually—as at the New Hope lodes—in well-defined joint fissures, or near the junction of the sedimentaries.

In many instances the wolfram is disseminated in very fine particles through the lode-rock for considerable distances; and the bismuth—when present in appreciable quantities—is also frequently as well distributed. This metal occurs as native bismuth, oxide and carbonate; the two latter as the result of oxidation of the first.

Scheelite, moreover, is regarded by well-known authorities as an alteration product of wolfram. A. Moncrieff Finlayson states that:—

> "Specimens of wolfram and scheelite in contact generally show the scheelite spreading along the cleavage planes of the wolfram, and replacing the darker mineral. This appears to be one of the chief modes of formation of scheelite in the Cornish veins." *

Dana, on the other hand, regards the converse as more common. However, so far as the Writer is aware, the Torrington deposits afford no evidence of either change.

Regarding the wolfram and bismuth as primary associates of the final aplitic phase of granitic intrusion, the chief factor of permanence naturally is the vertical and horizontal extent of such intrusions.

Quarrying has already revealed that the quartz-topaz ore-rock occurs not only as bosses and vertical dykes, but also in the nature of sills or sheet-like masses in the sedimentary rocks. The latter dip at low angles or follow wavy undulations. The undulatory courses of these sills probably result in apparently isolated contiguous hummocky outcrops; the underground connections of which future mining developments may reveal.

The following ideal section based on Hawkins' Quarries illustrates this probable mode of occurrence:—

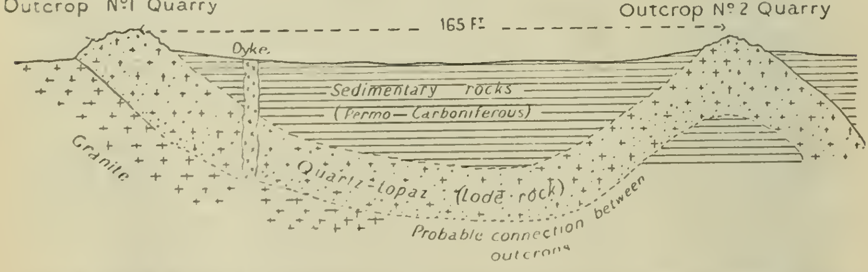

FIG. 6.—Ideal section of probable sill-like occurrence of ore-rocks in sedimentary rocks, Torrington.

A—Sedimentary rocks, locally known as "trap."

B—Aplitic ore-rock, locally known as "quartzite."

* Economic Geology, V, No. 8, December, 1910, p. 721.

Mrs. J. Shannessy.

Tungsten near Torrington.

Rockvale Wolfram Company. Entrance through Sedimentary Rocks to Second Quarry in Hawkins' Section.

Ore-rock..→

Mrs. J. Shannessy.

Torrington Wolfram Proprietary's Quarry in M.L. 75, showing Ore-rock rising from under Sedimentary Rocks.

At Hawkins' Lease (M.L. 18), in the Rockvale Company's property, the ore-sheet exposed in the principal quarry dips towards the new quarry on the north, and will probably connect with it in the manner depicted.

At No. 2 Quarry, in M.L. 75 of the Torrington Wolfram Proprietary, similar wavy undulations of the ore-sheet are exposed in a most instructive manner.

In some, at least, of the principal workings the ore-rock will be found to take this form of huge sheets or sills ; hence passing through them vertically need not cause apprehension if the true form is realised.

It is, moreover, probable that lower sills may be encountered which have no surface exposures.

Though in one direction these sills will be found to taper out, in the other they should be traceable to their source in the granite massif. Denudation, however, is a factor to be considered in this connection, for it may have caused breaks in continuity of the ore-sheet by removal of exposed areas originally forming ridges above the general level. The greater hardness, and therefore resistance, of the quartzose ore-rock, however, circumscribes the effect of denudation, save under exceptional conditions.

The Writer is of opinion that the persistence or permanence of the main ore-bodies is assured, though underground mining will probably have to take the place of quarrying where the overburden of sedimentary rocks is too great for economic removal. The quantity of lodestuff is undoubtedly very extensive, but the profitable proportion is a matter for adequate testing. The grade, at best, is low ; hence success depends on the scale of operations, and utilization of labour-saving appliances.

It is to be hoped that the duplication of the Rockvale Wolfram Company's crushing and concentrating plant at Black Swamp will definitely ascertain the minimum grade which can be profitably attacked under such conditions; of course relying on stable market values for the standard product.

In regard to the permanence of scheelite deposits at Hillgrove, whilst the individual lenses and thin veins of ore are extremely capricious in occurrence, there is no reason to doubt their persistence at great depths. In fact, Nature has already demonstrated this by exposing scheelite deposits in the sides and bed of Baker's Creek Gorge to a depth of 1,400 to 1,600 feet, or more. If the denuded material was restored it is more than probable that the fissures carrying the scheelite would outcrop at the surface, like those in the Freehold, and at Metz on opposite sides of the gorge.

This view is strengthened by the wonderful persistence of the extremely thin Smith's Gold Reef, in Baker's Creek Gorge, which outcrops about 1,500 feet below the level of Hillgrove, and which has been followed down in the Baker's Creek and Proprietary Mines for 2,000 feet, and still persists strongly.

VII.—DESCRIPTIVE REGISTER OF NEW SOUTH WALES TUNGSTEN MINES AND OCCURRENCES.

Albury, 4 miles N.W.—A sample of quartz containing wolfram purporting to come from this locality was assayed in the Departmental Laboratory in 1910, with the following result:—

10–45—Tungstic trioxide .... 16 per cent.

Alick Steyne Creek, Parish Highland Home, County Gough. G. W. Card records wolfram and scheelite from this locality to the north of Emmaville.*

Armidale District.—(See Hillgrove and Gara Falls.)

Back Creek.—26 miles from Armidale, and 7 miles from Birlong Station.—Wolfram in quartz veins traversing granite.

Barraba and Manilla (between).—Portions 134, 135, Parish Wilson, county Darling; also in Portions 42, 43, and 55, Parish Eumur, in the same county.

Barrier Ranges.—(See Broken Hill, Purnamoota, and Waukeroo.)

Bell's Claim.—The Gulf. E. C. Andrews states that the lode worked in this claim occurs in granite:—"Wolfram occurs in fissure containing abundant secondary mica (sericite), monazite, &c.; other small claims exist in the neighbourhood."†

Berridale, 1¼ miles south 20° west of.—Portion 123, Parish Coolamatong, County Wallace.

In 1891 Mr. Warden Love reported that permits to search for wolfram on W. Avery's conditional lease at Berridale, in the Parish of Coolamatong, were granted to Messrs. E. P. Margoschis, D. Murray, and N. Lockyer. The Warden also stated that a "broken outcrop of quartz, containing wolfram, was traced for 100 yards, running east and west. An assay of a small sample yielded 69 per cent. of tungstic acid."‡

In 1893 a sample of wolfram in quartz was assayed for 54·35 per cent.§

In 1894 a local syndicate (Margoschis and party) was formed to further prospect the lode. In the following year aid was granted from the Prospecting Vote, but the site was abandoned without anything of importance being discovered.‖

In connection with a further application for aid to prospect (08–2,703), it is recorded that three shafts had been sunk following the underlays of three separate veins of quartz in granite, carrying a little wolfram as isolated crystals in the quartz. The shafts ranged from 16 to 20 feet in depth, and about a chain apart.

Aid was granted to sink a vertical shaft 100 feet, to cut two of these veins on the underlay; neither, however, were intersected at that depth. Further aid was granted to cross-cut 75 feet southerly from 76-feet level. A reef was struck but carrying no wolfram.

In 1907 the site was examined by the Writer. Two thin quartz veins had been opened by trenching, and a shaft—probably the aided one referred to above—sunk between the veins.

The southern vein strikes N. 80° W., and dips N. 10° E. at 55 to 60 degrees; and is from 3 to 6 inches thick. Opened for several chains by trenching. Wolfram occurs very sparsely disseminated in the quartz.

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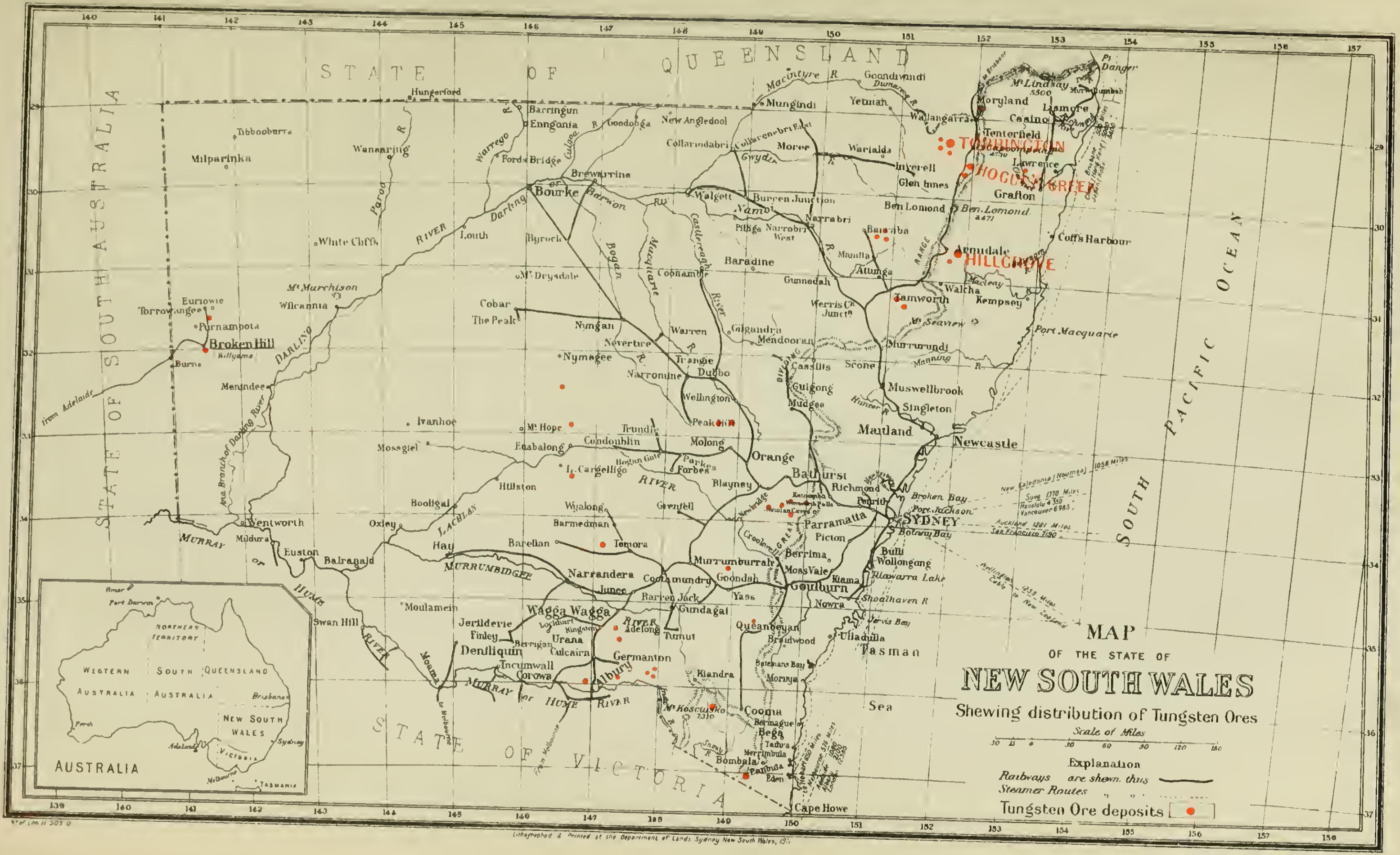
* Records Geol. Survey N.S. Wales, 1907, VIII, Pt. 3, p. 3. † Ann. Rept. Dept. Mines N.S. Wales, 1904, p. 143. ‡ Ann. Rept. Dept. Mines N.S. Wales, 1891, p. 91. § *Ibid.*, 1893, p. 50. ‖ *Ibid.*, 1895, p. 67.


MAP
OF THE STATE OF
NEW SOUTH WALES
Shewing distribution of Tungsten Ores
Scale of Miles
Explanation
Railways are shewn thus
Steamer Routes " "
Tungsten Ore deposits
STATE OF QUEENSLAND
STATE OF SOUTH AUSTRALIA
STATE OF VICTORIA
SOUTH PACIFIC OCEAN
Tasman Sea
TORRINGTON
HOGUE'S CREEK
HILLGROVE
SYDNEY
Newcastle
Broken Hill
Bourke
AUSTRALIA
Lithographed & Printed at the Department of Lands Sydney New South Wales, 1911

The northern vein, about 90 feet north, strikes N. 85° W., and dips N. 5° E. at 75°. Thickness about 3 inches. Opened by trench about 50 feet long and 18 feet deep. Wolfram occurring sparingly as in the south vein.

About 50 feet south of the deep trench the shaft has been sunk in granite.

On the western strike the vein has been opened at intervals for several chains beyond the deep trench. In numerous places in the vicinity of the veins shallow prospecting has been carried on for small "makes" of ore, which were dollied and hand-dressed. The output is not ascertainable, but it was evidently small.

Payable deposits are unlikely at this particular site.

Big Lode.—About 150 yards east of Toohey's Lode, Pulletop, Parish Burrandana, County Mitchell.

Discovered by M. Toohey about 1904, worked intermittently since. Strike N. and S.; dip slight to east. Opened for about 300 yards by a trench 10 feet deep. Wolfram occurs in a white quartz reef from 1 to 2 ft. 3 in. thick, at intervals of about 60 feet. Rich patches of coarsely crystallized wolfram occur in bunches but cut out rapidly in depth. About 4 tons of dressed wolfram obtained up to September, 1910. So far tin has not been found in association. The granite walls are well defined, and micaceous.

About half a chain east a small quartz reef containing wolfram has been opened, but unpayable so far as tested. This reef splits up in places, and dies out in others.

About 3 chains east of the Big Lode is another quartz reef, 6 inches thick, which carries both wolfram and tinstone, the latter mineral being confined to the walls. Strike N. and S. Dip east.

Occasional rich bunches of wolfram are found in this portion of the Pulletop Tin and Wolfram field, associated with quartz. One block of pure wolfram weighed $1\frac{1}{4}$ cwt. The occurrence of iron oxide is locally regarded as indicative of wolfram; in some bunches it partly replaces the latter near the surface owing to decomposition.

A few of the reefs or lodes were found to depart from the usual meridional strike as much as 20 degrees.

Secondary silicification has induced an appearance of gradual transition from normal granite to quartz in some of the lodes; the alteration effected extending into the walls for at least a foot.

Bingara.—An assay sample purporting to come from near Bingara was assayed in 1893 for 72·46 per cent. of tungstic acid.

Black Swamp.—Portion 397, Parish Rockglen, County Clive. David, in 1887, mentioned wolfram in this locality in veinstone consisting of cellular quartz, with nests of tourmaline and chlorite, with small bunches of tinstone. Average width, $1\frac{1}{2}$ inches.*

(See also Chinaman's Lode, Roberts' Lode, Smith's Lode.)

Bombala.—(See Mila.)

Bourke's Creek.—(See Pulletop.)

Bradshaw's Lode.—The Gulf. About $\frac{1}{4}$ mile east of Hutton's Lode; width, 10 inches; opened to a depth of 50 feet in 1909.

Described by E. C. Andrews, as a "true fissure lode, but very narrow. Gangue-chlorite, secondary mica, tourmaline, monazite, &c. The monazite occurs as lumps and grains."†

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* Geol. Veg. Creek, 1887, p. 121. † Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 143.

Recently a sample of crystallized wolfram from this mine was presented to the Mining Museum. The crystals are described by G. W. Card as of pronounced tabular habit, slightly curved, and overlying one another in a radial manner, the interspaces being occupied with creamy clay containing a little bismuth carbonate.

Brickwood Lode.—Alick Steyne's Gully, Parish Highland Home, County Gough. Strike N. 50° E. Opened by shallow cuts in granite.

Brown's Claim Lode,—The Gulf. Described by E. C. Andrews as wolfram in quartz, associated with secondary mica, tourmaline, &c., in granite.

Bryden's Lode.—Red Hill, M.L. 69, Parish Rock Vale, County Clive, near head of Dingo Gully.

Discovered about 1904. Opened by cut 15 x 15 x 8 feet (about). Occurs in biotite granite in part porphyritic. Lode strikes apparently N. 80° E. Lodestuff usual glassy aplitic or granular quartz-topaz rock, with small vugs lined with crystals of quartz and mica. Twenty-five tons treated in March, 1911, at the New Hope Battery for 5 cwt. 2 qrs. 12 lb. of concentrates, equal to about 1·1 per cent.

Bundarra.—A sample received from this locality (described as 25 miles S.W. of Tingha) in 1891, consisting of wolfram associated with arsenide and arseniate of iron in quartz, yielded 44·94 per cent. of tungstic acid.*

Burrowa District.—Two mining leases for wolfram were applied for in this division in 1890. Samples received for assay from 2 miles from Frogmore yielded 51·67 and 62·67 per cent. of tungstic acid.† Both scheelite and wolfram occur in the neighbourhood of Frogmore, but prospecting failed to discover these minerals in payable proportion.

Butler Tin Lode.—Portions 173, 174, &c., Parish Highland Home, County Gough.

Wolfram, frequently in well-developed tabular crystals, occurs on the hanging-wall side of the Butler tin lode, but no attempt has yet been made to separate it.

Carter's Back Lode.—On east fall of Carter's Hill, 1¾ mile N.W. of Pulletop, Parish Burrandana, County Mitchell.

Examined by E. C. Saint-Smith in September, 1910, who describes it as a white quartz lode up to 18 inches thick; strike N. and S.; dip slight to west. Opened many years ago at intervals for about 40 chains; and by two shafts 30 and 50 feet deep and 210 feet apart. In these shafts the lode averaged about a foot in thickness in granite. Wolfram occurs in shoots which are reported to cut out in depth.

Carter's Hill Lode.—On summit of Carter's Hill, M.Ls. 9 and 10, Parish Burrandana, County Mitchell, 1¾ miles north-west of Pulletop.

Discovered several years ago; intermittently worked since by J. Toohey, who sank ten shallow holes along the strike in a distance of 300 feet. Patches of wolfram occur in a white quartz lode in granite; about 3 cwt. of coarse crystallized wolfram obtained. About half a chain east a small quartz vein was opened containing crystallized tinstone and wolfram. Examined by E. C. Saint-Smith in September, 1910.

Carter's Lode.—Carter's Hill, ¼ mile north of Pulletop Creek, Parish Burrandana, County Mitchell.

Discovered by Carter in 1904, who sank 50 feet in a white quartz lode 8 inches thick. E. C. Saint-Smith examined the locality in September, 1910, and reported that the wolfram was replaced by marcassite at the bottom of the shaft. The lode has been opened at intervals for a length of 20 chains

* Ann. Rept. Dept. Mines N. S. Wales, 1891, p. 52. † *Ibid.*, 1892, p. 51.

by shallow trenches. Small bunches of wolfram occurred in isolated patches. Strike north and south, with slight westerly underlay, in granite. Several small parallel leaders have also been opened, though occasional large lumps of wolfram were found (one weighing 80 lb.); the work was not profitable.

Casino.—A sample, purporting to come from this district, was assayed in 1895, for a return of 75·3 per cent. of tungstic acid.*

(Probably Scheelite.).

Cathcart, 7 miles North.—Rubbly wolfram, yielded on assay in 1910:—

10–338 Tungstic trioxide .... 58·48 per cent

Cemetery Creek Lode.—On J. Newley's Annual Lease, $1\frac{3}{4}$ miles N.W. of Wilson's Downfall, Parish Ruby, County Buller.

Discovered about 1898 by Stalling and party, who worked it for some months; since intermittently prospected by others. The wolfram occurs in a quartz vein, about 8 inches thick, traversing coarse granite, the quartz being bounded by narrow selvages of greisen, which is also traversed in places by thin quartz veins. Strike of lode, N. 70° E.; dip slight to S. 20° E. The wolfram occurs mostly in the centre of the quartz vein, but a little also in the greisen, where quartz traverses it. A small percentage of sulphide and native bismuth are associated. Opened for about 300 feet by shallow holes along the crop, the deepest 24 feet. Some rich patches were obtained, but mining has ceased for some years.

Chinaman's Lode.—Black Swamp, 5 miles N.W. of Torrington, Parish Rock Vale, County Clive.

Worked to a small extent for many years; it consists of pegmatite in acid granite. The wolfram is mainly crystallized with the biotite, practically enveloping individual crystals. The biotite has been developed on either side of the original fissure.

Clapham's and Townsend's Lode.—E. C. Andrews states that the occurrences in this site are in granite, and of irregular shape. The wolfram occurs in masses of quartz, with excess of amorphous arsenical pyrites and beryls. Much secondary mica and a little fluor-spar also occur.†

Coghlan's Lode.—About 20 chains west of Davison's Lode, The Gulf, Parish Muir, County Gough; strike N. 50° E.; opened by shaft about 30 feet deep.

Condobolin.—(See Mt. Tallebung.)

Coppabella.—(See Musgrave's and Gifford Mines.)

Copeton.—(See Pepp's Flat.)

Cosgrove's Lode.—Between Dixon's and Mossman's Gullies, Parish Ruby, County Buller, near Wilson's Downfall, Stanthorpe-road, about 6 miles N.W. of the former.

Discovered by T. Cosgrove about June, 1907, and worked about a year.

Wolfram and tinstone occur at this site, so far as the limited proving reveals, in bunches or "blows," and not in defined lodes. When examined by the Writer in October, 1908, a few shallow openings had been made in three separate outcrops. The most western consisted of a large quartz blow which had previously been quarried for road metal. Wolfram occurs very sparingly in scattered plates in the quartz.

About 2 chains east two other outcrops had been superficially tested, the southern yielding a few patches of wolfram, the matrix being aplitic granite. Close by a tin lode was cut, from which about 3 cwt. of dressed tinstone was obtained by hand spalling and jigging.

* Ann. Rept. Dept. Mines N. S. Wales, 1895, p. 67. † Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 143.

A shaft sunk to 25 feet in the best wolfram show passed into tin-bearing lodestuff at bottom; the difficulty of separation is reported to have prevented further effort. The wolfram lodestuff was roasted, crushed with spalling hammers, and jigged in a roughly extemporised jig. Three tons of wolfram were reported to have been obtained to October, 1908.

Cow Flat.—(See Cow Flat and New Hope Mines.)

Crowe's Claim.—On north boundary of Portion 88, Parish Rock Vale, County Clive, about 10 chains east of Elliot Bros.' Wolfram Mine at Dingo Gully, and on same line of lode. Site was originally prospected by T. Johnson, about 1904, to a depth of 35 feet, when the ore pinched out. Four tons of wolfram are reported to have been obtained.

Cow Flat Wolfram and Bismuth Lode.—M.L. 203, Parish Rockvale, County Clive.

This mine was held and worked by the original Wentworth Proprietary Company (now Rockvale Wolfram Company, Ltd.), but was abandoned in favour of the new scene of operations at Black Swamp—where the machinery has been incorporated in the new plant.

The lode was worked by open cut and shaft—extending a horizontal distance of about 300 feet at the junction of granite and sedimentary rocks. The latter consists of claystones and sandstones. A sample of the granite was petrologically examined by G. W. Card, who described it as follows:—

[7926]

Granite—biotitic and topaz-bearing. Medium in grain, but pegmatitic in places.

Colour—light, poor in mica.

Under the microscope, two micas are seen, and considerable topaz.

There seems to have been an intermixture of magmas."

A 10-head battery was erected in connection with this mine; and concentrates to the value of £2,400 were obtained during 1907.*

Davison's Lode.—West of Gulf Creek, Parish Muir, County Gough. Strike N.E. Shaft sunk about 20 feet in chloritic quartzose lodestuff containing wolfram, copper pyrites, and fluor-spar. About 12 tons of ore are reported to have been won from this lode.

Deepwater, 10 miles N.E.—Wolfram in small quantity occurs in this locality; but has not been worked.

Dine Dine.—(See Mt. Tallabung and Erimeran.)

Ding Dong.—C. S. Wilkinson recorded wolfram associated with tinstone at Ding Dong:—"Near the junction of the slate formation and granite, the latter, which is coarse-grained granite, contains irregular-shaped masses of greisen rock, composed of quartz and mica in varying proportions. These masses appear to have been formed by segregation."† Ding Dong is situated between Deepwater and the Great Dividing Range.

Dingo Gully.—(See Elliott's and McMullen's lodes.)

Dodger Lode.—On north boundary of Portion 92, Parish Rock Vale, County Clive, close to south-west head of Dingo Gully.

Discovered about June, 1910. Strike E. and W. Held by J. McMullen, on same line and 2 chains from Welcome Stranger Mine. Opened by shaft to a depth of 20 feet in August, 1910. Wolfram occurs in chlorite and quartz in coarse lumps. About half a ton of clean ore obtained to date mentioned.

Donohoe's Lode.—Alick Steyne Gully, Parish Highland Home, County Gough.

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* Ann. Rept. Dept. Mines N. S. Wales, 1907, p. 65. † *Ibid.* 1883, p. 151.

Discovered by Donohoe Bros. in November, 1908. Strike N. 35° E. Lode channel about 2 feet wide. Veinstone mostly quartz, but passing into quartzose-chlorite with depth. Opened to 22 feet from surface in February, 1909, and driven 20 feet north-easterly. Wolfram showing in the outcrop for 40 or 50 feet. Richest pockets in soft chloritic lodestuff. About 2½ tons of clean wolfram extracted to date mentioned.

Duckmaloi Creek, Oberon District.—Wolfram in large pieces is recorded from Duckmaloi Creek,* probably identical with Kirk and Dwyer's find near Oberon. (See Oberon.)

Dundee.—(See Hogue's Creek.)

Eason's Find.—(See Mt. Tallabung and Erimeran.)

Elliott and Hore's Lode.—Parish Bates, County Clive, on divide between Bob's Swamp and Moleyard Creeks. Discovered by C. E. Elliott and James Hore about February, 1911.

Quartzose lodestuff containing wolfram and carbonate and oxide of bismuth, in biotite granite country. A small oval outcrop about 1 chain in diameter has been opened in two places to a depth of a couple of feet. The metallic ores appeared to be well distributed, forming good concentrating material. Too little work yet performed to allow of an estimate being made as to extent of deposit. The distance from the nearest milling plant is about 3¾ miles in a direct line.

Elliott Bros.' Wolfram Lode.—On north boundary of Portion 90, Parish Rock Vale, County Clive, in south-west branch of Dingo Gully. Discovered by Elliott Bros. in March, 1910, by following trail of shed wolfram whilst boring Dingo Gully for tin-dredging purposes. The so-called "bung" occurs in a well-defined line of lode striking about N. 85° E., and traceable for a considerable distance. The lode was opened on the east side of Dingo Gully several years previously.

Elliott's "bung" was decidedly the richest deposit, so far as proved, yet discovered in the State. At the time of inspection (August, 1910) the shaft was 40 feet deep, and the ore was solid and strong at that level. The cap of the lode, which strikes across Dingo Gully, was covered by 5 feet of alluvial. In the decomposed cap two 50 lb. blocks of pure wolfram were obtained at 9 feet from surface; below this a 5 cwt. slug of pure ore was obtained in the soft channel filling. Eight tons of clean wolfram were obtained in 8 feet of sinking in the shaft. To the 5th August 9 tons had been despatched, and several tons were at grass.

The lodestuff consists of chlorite, felspar and quartz, with wolfram in massive pockets. Beryl is also present in acicular crystals. The quartz is relatively scarce, occurring chiefly as crystals (white and smoky) in vugs. A few specks of purple fluor-spar are occasionally seen. Cassiterite occurs rarely, chiefly in vugs.

This shaft was continued to about 50 feet. The wolfram is reported to have cut out at about 45 feet. Altogether, 15 tons were obtained from this shaft. No driving has been done along the lode, though other shoots may occur.

Elsmore Hill.—Parish Anderson, County Gough. A wolfram lode in granite in this hill, was opened by P. Griffiths to a depth of 15 feet. Then by J. Botteril, who extracted about 1 ton of wolfram in 1902, whilst the Union Tin Mining Company held the land. The site being on the eastern fall of Elsmore Hill towards the Macintyre River.

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* Records Geol. Survey N. S. Wales, 1903, VII, Pt. 3, p. 219.

Reopened early in 1910 by H. B. Smith, of Inverell, 1 ton 2 qrs. 14 lb. of wolfram being obtained from a shoot 12 inches by 2 inches, which is reported to have cut out at 30 feet.

Wolfram is sparingly disseminated through quartz veins and in miarolitic cavities in the Elsmore granite—usually associated with smoky quartz crystals.

Emmaville District.—In 1887 David referred to the occurrence of wolfram and scheelite in this district whilst describing the tin deposits :—

> "An important vein of wolfram occurs on the Mole Tableland, 13½ miles north of Emmaville in a direct line, but 21 miles distant by road. (Parish Rock Vale, County Clive.—J.E.C.) The point, at which the reef was observed to be rich in wolfram, bears west 36° south from the south-west corner of Portion 407, Parish Rock Vale, County Clive, a quarter of a mile distant, and lies just outside the boundary of this parish, in the north-east corner of Parish Flagstone, County Gough. The vein is, in places, from 10 to 12 yards wide, though probably not metalliferous throughout its entire width. Owing to the reef being covered over with sandy soil, it is impossible to ascertain, by mere inspection, the average width or length of its outcrop, though surface indications favour the supposition that the reef is a strong one. The strike is about N. 40° E. As far as I am aware, this reef has never been prospected, and it is situated partly on Crown lands."

If this lode has not received attention of late years it is worthy of further prospecting, as some very rich bunches have recently been found in the vicinity. (See Elliott Bros. and the Dodger Lodes.)

> "Wolfram also occurs at the Gulf Main vein, Hall's Grampians, Lee's Gully, and the Planet Mine, near the head of the Nine-mile Creek, Parish Wellington Vale, County Gough.
>
> "Scheelite has been found in small quantities at McDonald's veins, on the Glen Creek. The mineral is honey-coloured and translucent."*

Erimeran Range.—At south end, about 9 miles from Erimeran head station, wolfram was discovered in this locality by Mr. George Eason about 1890 at the time of the gold discovery at Mount Allen. In 1892 several assays made in the Departmental Laboratory from the Mount Hope district—which broadly defined the tin and wolfram localities—yielded from 62·57 to 72·2 per cent. of tungsten trioxide.

Eason opened his discovery to a depth of about 14 feet. A local syndicate (J. Lynch and party) took up a lease in May, 1896, and sank several shafts: No. 1, to a depth of 50 feet, was driven 15 feet. Shallow shafts were sunk along the outcrop for a distance of 8 or 9 chains, which is reported to strike north and south. The occurrence is in quartz veins in slate. The largest piece of wolfram ore weighed over 1 cwt. Three tons were despatched (not concentrated), but no returns of this early consignment are available.

Essington, Rockley District.—(See Mt. Sromlo.)

Eurambie.—(See Mt. Tallabung.)

Fielder's Hill.—(See Torrington Ore Company.)

Flynn Bros.' Lode.—The Gulf. Described by E. C. Andrews in 1904 as a :—

> "True fissure in granite. *Ore.*—Wolfram in lumps, as much as 5-lb. weight specimens. *Gangue.*—Quartz and pegmatite (?). Workings.—Two shafts, 20 feet and 35 feet."†

Frogmore.—(See also Burrowa.)

* Geol. Vegy Creek, 1887, pp. 161-2. † Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 143.

In 1906 Inspector Smith examined a quartz vein in slate, carrying a little wolfram and scheelite, 4 miles east of Frogmore, on Reed's Flat road, 16 miles from Burrowa, Portion 70, Parish Alton, County King. The vein had been opened by shafts and trenches for about 300 feet along the strike. The thickness varied from 15 inches to 18 inches.

Aid was granted to sink the 50 feet shaft a further 50 feet. At 60 feet the vein was 4 inches thick, carrying a little wolfram. At 75 feet it was but 2 inches, with a little wolfram and scheelite.

Gara Falls.—(See Hillgrove.)

Germanton, 12 miles north of.—Parish Back Creek, County Goulburn. Tinstone and scheelite is reported from this locality.

Glen Eden Lodes (see also Hogue's Creek) P.M.A. 5 and 6, in Portion 88 E. Newsome's freehold, Hogue's Creek, Parish Boyd, County Gough, about 12 miles northerly from Glen Innes, near Tenterfield-road.

Prospected as early as 1883 for wolfram, tin and bismuth,* and at a later date for wolfram by C. S. McGlew. A quantity of wolfram was raised by E. J. Newsome in 1910, valued at £700.†

Reopened in January, 1910, by Sir Albert Gould and others, under the name of Glen Eden Mine, and a crushing and concentrating plant erected on P.M.A. 5, consisting of a No. 2 Dodge rock-breaker; 3 ft. 6 in. Huntington mill, with screens of 144 holes to the square inch; and an Imperial Woodbury concentrating table.

At this site masses and veins of quartz traverse quartz-porphyry near junctions of sedimentary rocks. Greisen is also developed on the margins of the porphyry. Massive quartz, with vugs lined with large crystals, occurs prominently in places. The quartzose lode-rock, however, partakes more of the character of the Torrington ore-rock, and will prove to be intrusive.

The metallic minerals—wolfram, molybdenite, and bismuth—are associated with the quartz and quartzose rocks, whilst cassiterite occurs in the greisen in well-developed crystals.

Wolfram occurs in irregular, isolated bunches, principally in thin parallel plates in quartz, but occasionally in the form of solid slugs. Some of the quartz masses are vertical, others dip flatly. At shallow depths, others pinch out in the porphyry. The isolated character of the ore bunches, unfortunately, necessitates excessive dead-work in the blanks.

So far, mining has taken the form of open-cutting and trenching for the most part, wherever ore-makes occurred. Wolfram is visible over a considerable area, and the question to be decided is whether mining on a large scale, by quarrying and bulk treatment, can be profitably maintained. It would, therefore, be wise to use the existing treatment plant to this end, by direct experiment with a given quantity from the most favourable open cuts.

Hitherto the practice has been to follow the small rich bunches, which may remunerate working miners with primitive appliances whilst values are high, but which would certainly prove unprofitable to a company.

Since the present holders took possession, 200 tons of hand-picked and dressed ore were crushed and concentrated for a return of 7 tons of concentrates, averaging about 64 per cent. of tungstic oxide.

Bismuth is present, to the extent of 5 per cent. in one parcel of "seconds" assayed, but the average in the total concentrates is not commercially regarded. Molybdenite is also insignificant. Cassiterite is prominent in one small vein, which could be profitably extracted so far as exposed, but its persistence is unproven.

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* C. S. Wilkinson, Ann. Rept. Dept. Mines N. S. Wales, 1883, p. 154. † *Ibid.*, 1910, p. 57

In 1883, C. S. Wilkinson described tin, bismuth, and wolfram in the Glen Innes district in the following terms :—

"About 12 miles north from Glen Innes, and about one mile east of the Tenterfield-road, several bismuth and tin-bearing quartz veins have oeen discovered. (Glen Eden.—J.E.C.) These occur in a different manner from those of Kingsgate. They form irregular veins and masses of quartz traversing a fine-grained micaceous felsitic rock, which is surrounded by altered sedimentary rocks. In one place this rock for a length of about 100 yards and a width of 15 yards is traversed by a net-work of quartz veins. A small hole has been sunk here, and the stone taken from it contains bismuth ores, cassiterite, molybdenite, arsenical pyrites, and wolfram. In another place, about 100 yards from that last named, a mass of hard crystalline quartz, in size at the surface about 40 feet by 20 feet, has been opened for a few feet in depth. It contains bismuth and tin ores, together with a large quantity of wolfram."*

Granite Springs.—Parish Waukeroo, County Yancowinna, Barrier Range. C. S Wilkinson recorded wolfram in a quartz reef, near the Granite Springs tin lodes.†

Gulf Creek Lode.—Portion 23, Parish Muir, County Gough. David recorded wolfram in small quantities associated with the Gulf Creek tin lodes.

Hall's Grampians.—Portion 101, Parish Strathbogie North, County Gough. The occurrence of wolfram was first noted in this locality by G. H. Gower, Mining Registrar, in 1875.‡ In 1887, David recorded a vein in the above portion from 2 to 3 feet wide; striking N. 63° E., and underlying N. 27° W. The veinstone being friable cellular quartz containing arsenical pyrites, tinstone and wolfram.§

Hawkins' Lode.—Oakey Creek, close to Torrington—Silent Grove road.

Strike N. 50° E., in granite. Width about 14 inches. Lodestuff mostly quartz; partly as comby crystals, partly banded. Opened to shallow depths in two places. Wolfram showing in north-eastern opening. Picked sample yielded :—

11-913— Tungstic acid ....9·55 per cent.
No bismuth.

Heffernan Bros.', Wolfram Lode.—M.L. 52, Parish Highland Home, County Gough.

Discovered about 1906. Proved by shallow shafts and trenches for a length of about 400 feet. Deepest shaft 40 feet. Strike, N. 30° E., in granite. Lodestuff at south end soft decomposed micaceous rock, with vugs containing quartz, felspar, and mica crystal aggregates, and occasional prisms of beryl. Wolfram occurs in bunches—not continuous. At north end hard aplite makes, with a little wolfram leanly distributed. The wolfram won so far has been obtained in the decomposed southern portion, usually as slugs, also with quartz crystals representing vugs.

Lode partly worked by Heffernans', partly on tribute. About 12 tons of dressed wolfram obtained to March, 1911.

Hogue's Creek.—(See Glen Eden.)

Hughes' Wolfram Lode.—On west side of Wilson's Downfall–Stanthorpe road near Amosfield; 1 mile north-west of Wilson's Downfall. Parish Ruby, County Buller.

Discovered about 1898; worked mainly by Rees Hughes in 1907–8 for about eight months, who opened it by a trench 40 feet long and 9 feet at deepest.

* Ann. Rept. Dept. Mines N. S. Wales, 1883, p. 154. † *Ibid* 1887, p. 143. ‡ Ann. Rept. Dept. Mines N. S. Wales, 1875, p. 108. § Geol. Veg. Ck., 1887, p. 127.

Examined in 1910 by E. C. Saint-Smith, who described the wolfram as occurring in a bluish-white quartz vein, varying from 8 to 15 inches in width, which splits and reunites repeatedly, small lenticular "horses" of aplite being enclosed by the quartz. Wolfram occurs in patches, principally in the central portion of the vein. It is associated with a little iron and copper pyrites, metallic bismuth, bismuth carbonate, and flakes of molybdenite.

Thin veins of quartz extend from the main vein into the aplite. The quartz is crystallized in part. The lode traverses aplite for the most part, but where it passes through coarse granite it is bordered by micaceous granite. The lode has been opened by small potholes for a length of about 600 feet.

Hughes is reported to have obtained about 18 cwt. of dressed wolfram during his operations.

Hutton's Wolfram Lode.—West of Gulf Creek, The Gulf, Parish Muir, County Gough.

Strike N. 60° E. Opened for a length of about 4 chains. Fluor-spar conspicuous, also chalcopyrite. Occurs in chloritic veinstone with crystalline quartz in vugs and small veins. Width from a thread to 2 feet.

Opened to 60 feet. Output, 4 to 5 tons dressed wolfram. Patchy.

Jingellic, Upper Murray River. Parish Jingellic, County Goulburn.

E. F. Pittman, in 1881, recorded the presence of wolfram, in the Jingellic tin-lodes which consisted of quartz veins traversing granite. The presence of wolfram and the failure to realise on the concentrates containing this mineral, was believed to have operated against the prospects of the tin-field. According to local report, 9 tons of mixed concentrates obtained during early operations failed to obtain sale.

Lankey's Creek.—(See Mt. Gifford.)

Lindner's Wolfram Lode.—Adjoining west boundary of Portion 13, Parish Burrandana, County Mitchell, on south side of Carter's Hill; $1\frac{3}{4}$ miles N.W. of Pulletop.

Discovered by August Lindner about 1904, and worked for about twelve months. Opened for about one-quarter mile in length. Strike N. and S. The wolfram occurs in patches in a white quartz-lode in micaceous granite; the width of which varies from 6 inches to 1 foot; but much split up into thin veins. Lindner also opened a small quartz leader carrying wolfram near the east boundary of Portion 13, about 5 chains north of Bourke's Creek.

Lode Hill Tin and Wolfram Lodes.—Queensland Border. M.Ls. 21, 22. Parish Ruby, County Buller, $3\frac{1}{2}$ miles W.N.W. of Wilson's Downfall. Country—coarse acid granite with aplite dykes, traversed by a great number of small quartz veins and micaceous (or greisen) bands, in which occasional payable patches of tinstone and wolfram occur.

Opened by several shafts and a considerable amount of trenching, but the total output of tin and wolfram is insignificant.

Most of the veins strike N.E., but a few strike N.W. Messrs. Sampson and Cokehill obtained 1 ton of dressed wolfram and 7 cwt. of mostly coarse tinstone from one of these lodes. Their width varies from that of a knife-blade to 3 feet. Lode matrix quartz (frequently highly crystallized) and micaceous granite.

The quartz veins on Lode Hill are nearly all found to split into a number of smaller veins at a shallow depth. In one case a flat vein—a few inches in thickness—yielded 3 tons of coarsely-crystallized tin ore. Several large lumps of solid wolfram have been found on the hill. The ore from these lodes was crushed at Lode Creek Battery (Queensland).

Louis' Wolfram Lode.—East side of Bald Hill; half a mile north of Bourke's Creek; Parish Burrandana, County Mitchell; 2 miles N.W. from Pulletop Homestead.

Discovered by Carter about 1904. Strike N. and S. Dip slightly east. Width 2 feet. Opened by shaft to 50 feet; width reported constant. A rich shoot of wolfram was met with at surface, which cut out rapidly in depth. Lode material—white quartz, in granite country. Walls well defined, and altered to greisen for about 6 inches from lode.

About 2 chains south of the shaft Louis Garrard opened a trench for 50 feet along the outcrop to a depth of 10 feet, from which he obtained 5 cwt. of coarsely-crystallized wolfram.

From the hanging wall side of the trench John Toohey obtained a small quantity of coarse tinstone in a clay seam. Attempts to work this lode were also made by C. McLeod and Theodore Lindner, but operations by them ceased in 1907. It is now intermittently worked by John Toohey. It has been traced for upwards of half a mile. Several vugs, with crystallized quartz, wolfram, and occasionally tinstone, were found.

McAlister's Lode.—At head of Herding Yard Creek, on north side of McPherson's Range, close to Queensland border; Parish Ruby, County Buller; 2½ miles W.N.W. of Wilson's Downfall.

Discovered by S. McAlister about 1906, and worked by him for a few months. Strike N. 80° E. Dip slight to westward; in coarse even-grained biotite granite, the biotite being usually replaced by muscovite immediately adjoining the reef.

The gradation from the country to the reef being in the following order:—

Coarse, even-grained biotite granite, with pink felspars.

Fine-grained greisen traversed by thin veins of bluish-white quartz.

Crystallized clear white and bluish-white quartz, with small lenticular bands of greisen, and tabular and acicular crystals of wolfram.

The wolfram occurs in streaks and bunches through the quartz, at distances varying from 15 to 20 feet apart; rich bunches occurred at the surface, but not of any great size, only a small amount of wolfram in the aggregate being won. Opened for a length of about 100 feet to a depth of 8 feet.

McGeoch's Lode.—Near west boundary of Portion 13, Parish Burrandana, County Mitchell, 1½ miles N.W. of Pulletop Homestead, on east fall of Carter's Hill. Opened to a depth of 20 feet in the form of an underlay stope, wolfram and tin being associated in the lode. Aided to sink a further 50 feet (P.B.09–669); no further report as regards test under aid.

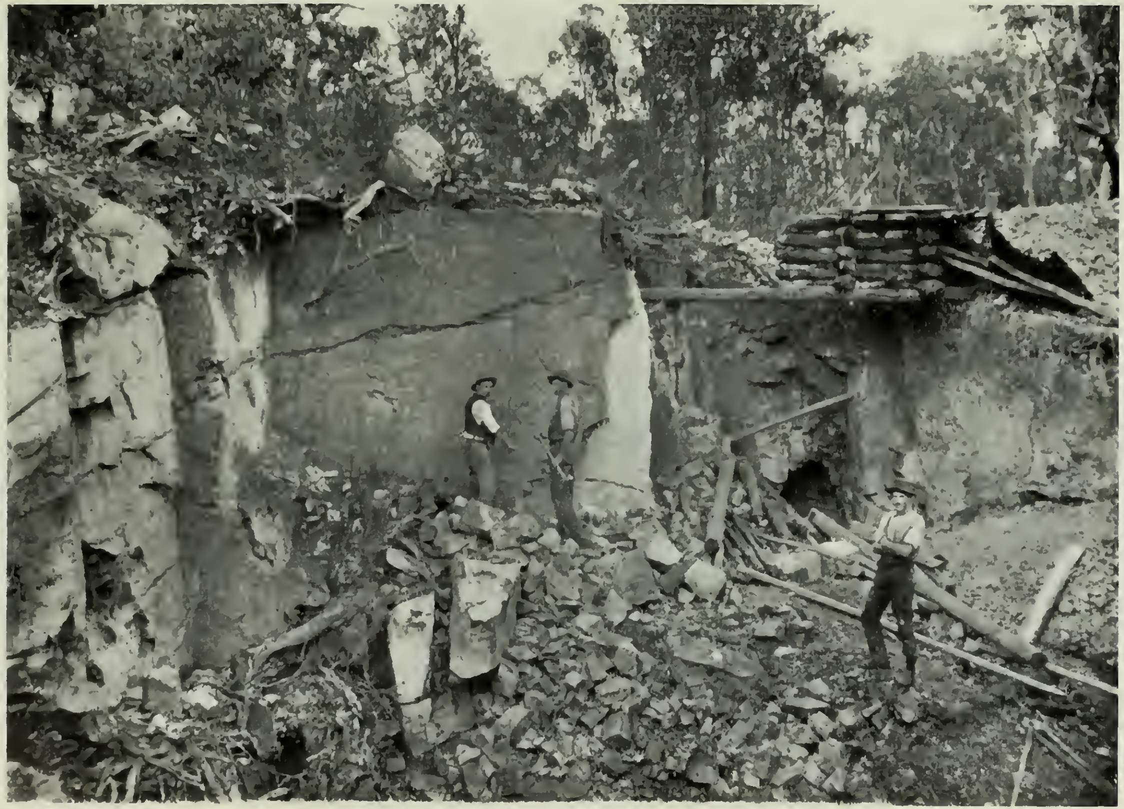
Examined by E. C. Saint-Smith, Field Assistant, in September, 1910, and described as a "white quartz reef, averaging about 16 inches in width, carrying copper pyrites, mispickel, iron pyrites, tinstone, wolfram, and zinc blende, with much white mica. Country rock—granite. Strike of reef N. and S."

Two chains east of the aided shaft McGeoch opened a white quartz reef (18 inches wide) in hard granite, at intervals for a distance of about 200 yards, by trenches. Numerous slugs of limonite occur. Strike N. and S. Lode much split up into thin veins in parts.

McLeod's Wolfram Lode.—About 3 miles north of Pulletop Homestead.

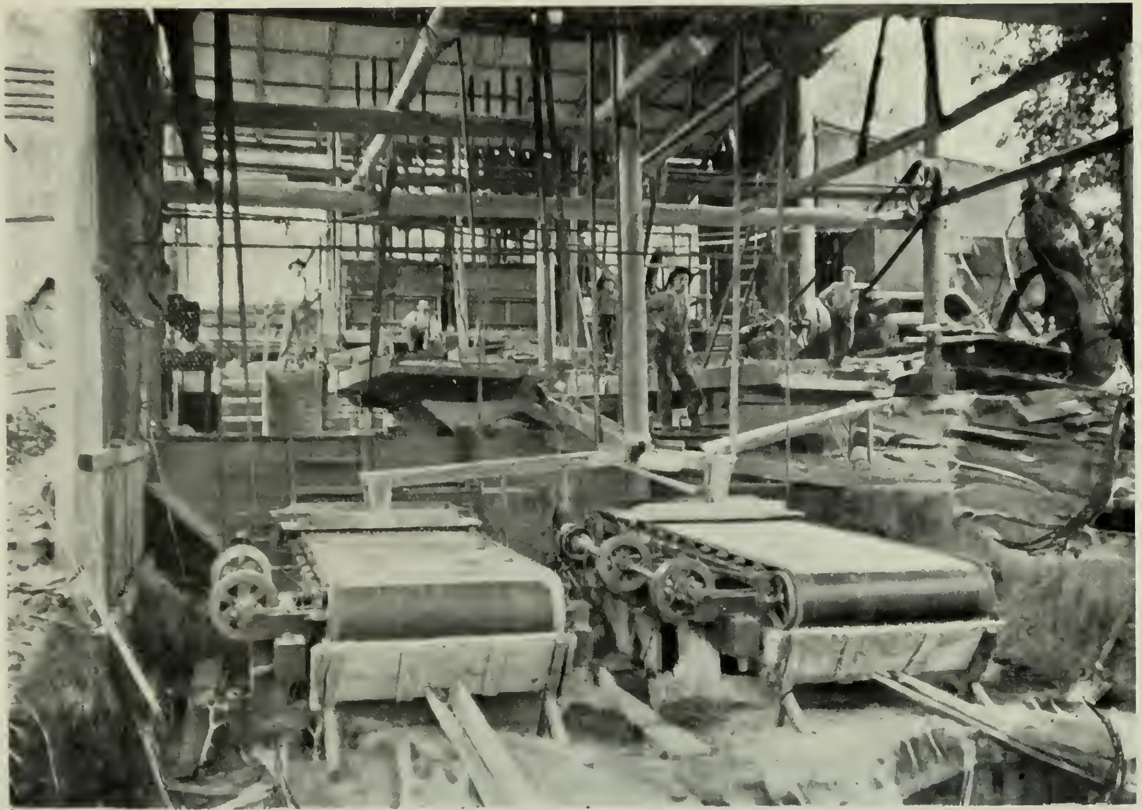
A white quartz reef in granite from 3 to 12 inches wide, but much broken. Strike N. and S. Coarse crystalline wolfram occurred, but no tin; about 1 ton of dressed ore reported to have been obtained. Discovered by Chas. McLeod about 1906, and worked by him and others intermittently.

McMullen's Prospecting Claim.—Head of Dingo Gully, Parish Rock Vale, County Clive.



T. H. Nicholas.

Mount Everard Wolfram and Bismuth Quarry, near Torrington.



T. H. Nicholas.

Mount Everard Battery and Concentration Plant (under reconstruction).

In March, 1911, J. McMullen—one of the original proprietors of the Dodger and Welcome Stranger Wolfram Mines, near by—was trailing wolfram up a branch of the head-waters of Dingo Gully, above Elliott's lode, to locate a lode or "bung." To this end he was stripping the over-burden. In the bed-rock the rotted outcrop of an ore channel was located in which a small "bung" occurred. A 4 lb. lump of wolfram was found on the bed-rock, as well as prospects of fine shed wolfram; also large loose boulders of the true ore-rock, which must have been transported from an outcrop not far away. The wolfram is unworn, and probably has not travelled far.

Mila, 14 miles south of Bombala.—M.L. 110, Parish Mila, County Wellesley. Discovered by F. G. H. McLeod, about 1896, on Mr. Cochrane's property near Mila.

The wolfram occurs very leanly distributed in a quartz reef striking N.E.

Mt. Everard Wolfram and Bismuth Mine.—M.Ls. 20 and 25, Parish Highland Home, County Gough, about 6 miles from Torrington Post Office.

Wolfram and bismuth occur in quartz-topaz rock, at the junction of sedimentary rocks, the contact striking approximately north-east. Worked by an open cut about 60 feet by 30, to a depth of 35 feet in one part. Ore-bearing rock has been traced for a length of about 600 feet in M.L. 25.

In the principal quarry the ore is split by a horse of sedimentary rock, blocks of which are engulphed in the intrusive aplite.

Early in 1909 the mine was let on tribute to Messrs. Williams and Stafford, who erected a 10-head stamp battery, with Wilfley table and two Frue vanners for concentrating. The power plant consisted of two boilers, one a vertical (Hoskins) boiler of 9 h.p., for pumping purposes, and one horizontal of 6 h.p., for driving two engines for crushing and concentrating machinery. This plant was installed for a half-share of the mine. Half the net profits to go to the original owners. The venture, however, was not successful no profit being made; the mine eventually falling to the original owners, Messrs. Payten and Henry.

The Writer again visited Mt. Everard in March, 1911, when a new plant was being installed, consisting of a 10-head stamp battery of 9 cwt. stamps, 7-inch drop, proposed to be run at 100 drops per minute. A $12\frac{1}{2}$ h.p. Shanks' Caledonian engine ($10\frac{3}{4}$-inch cylinder) for battery; vertical Tangye boiler, 8 h.p.; and 6 h.p. engine for concentrating plant.

Battery discharge 4 ft. 6 in. by $14\frac{1}{2}$ in. Screens 64 holes per square inch; wire-wove.

Pulp to pass direct from battery on to two Wilfley tables; the "cut-off" to two Frue vanners. Tailings from vanners to two dead buddles 6 ft. 3 in. diameter. Tailings from tables and buddles to pass over blanket tables to discharge.

Mt. Stromlo.—Brisbane Valley, Rockley district, M.L 13, Parish Baring, County Westmoreland. Area, 20 acres.

Taken up by D. S. Todd and party, 24th August, 1906. Shaft sunk in quartz lode to 100 feet. Wolfram occurs leanly distributed in the quartz. About 1 ton of concentrates were obtained by bucking and sieving.

Mt. Tallabung.—Parish Urambie East, County Blaxland, about 45 miles N.W. of Condobolin.

Wolfram was discovered by G. Eason in this locality in 1892, several assays being made in that year in the Departmental Laboratory for results ranging from 62·5 to 72·2 per cent. of tungsten trioxide.

In 1910, M. Morrison, senior Field Assistant, visited the locality, and supplied the following notes on the mode of occurrence and output:—"The wolfram occurs in irregular bunches in quartz veins at the northern end of the Tallabung tin leases. A little tin is disseminated through the quartz also. The provings are only superficial, and extend for a distance of over a quarter of a mile. From the nature of the workings the ore bunches do not appear to have been very extensive. Practically, the whole of the surface ore has been worked out. It is stated that about 8 tons of wolfram concentrates have been despatched from the field. Mr. J. Talbot supplied the following particulars of ore despatched by him :—

Tons.	cwt.	qrs.	lb.	Assay– WO_3%.
2	1	3	7	66·74
0	16	3	16	57·19

Mulyan.—C.L. 6,079, Parish Kikoira, County Dowling. In 1906 the presence of wolfram in small quantity with tin ore, was noted at Mulyan.*

Musgrave's Wolfram Lode.—On north fall of Mount Gifford, 3 chains east of 44-feet shaft on Musgrave's Tin Lode, Parish Currajong, County Goulburn, near Lankey's Creek.

Discovered by W. Musgrave in 1897. A small quartz vein, with a little wolfram in greisen. Strike N. 30° E.

Nangeribone, near Nymagee.—Wolfram reported.

Newsome's Wolfram Lode.—(See Glen Eden Mines).

New Hope Mine.—M.Ls. 22, 23, 200, Parish Rock Vale, County Clive. August Beil, Wynyard Chambers, Wynard-square, Sydney.

Operations commenced about 1903–4. Thirty to forty tons of wolfram concentrates shipped annually since; containing about half to one per cent. of bismuth.

The ore is now won wholly on tribute; the Company crushing and concentrating for the tributers, and paying an agreed price per ton for the concentrates.

The crushing plant consists of a 10-head stamp battery; weight of stamps, each 800 lb. Drop 4 to 8 inches according to class of ore; rate, 90 to 120 falls per minute. Wire-wove screens of 64 holes to the square inch.

Concentrating plant—consists of one Wilfley and one Woodbury table, and four Frue vanners. At the present time half this plant—both crushing and concentrating—is in use. The pulp from the battery going directly to a Wilfley table; middlings and slimes to Frue vanners. Residues from vanners are further treated on a sweep buddle, the centres of which are re-treated over Wilfley and vanners.

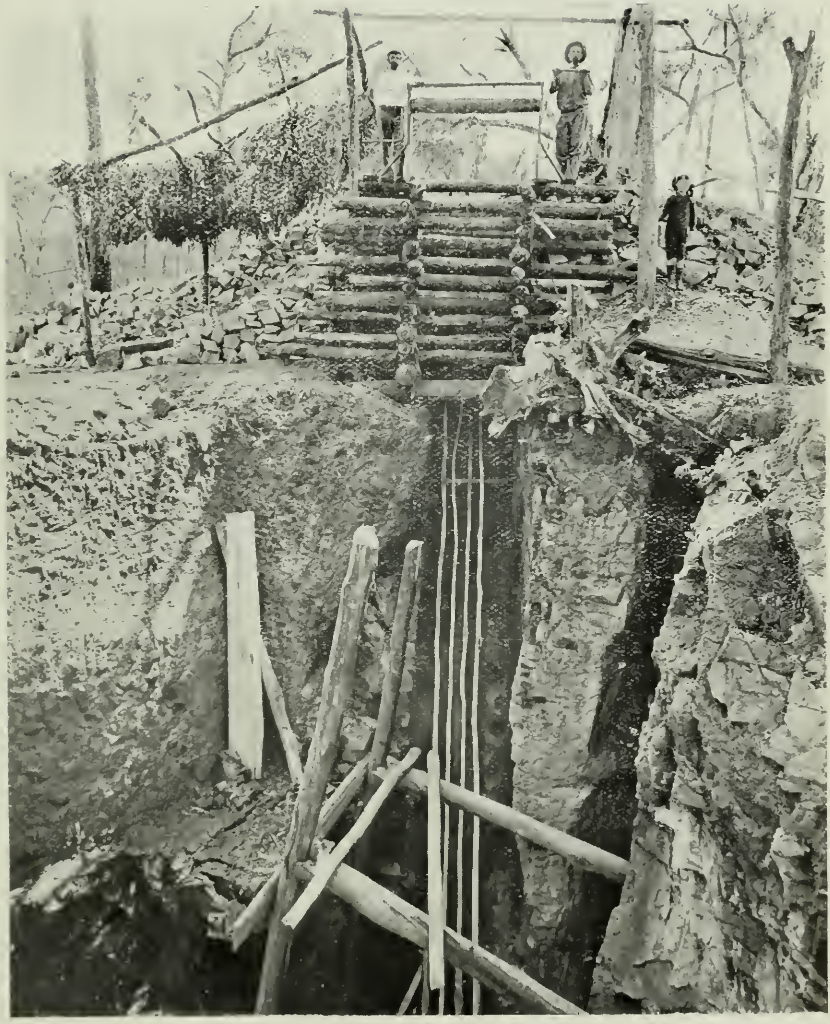
Two chains trailing on the buddle close to feed cause ripples and prevent guttering; wolfram concentrates rarely pass the ripples thus formed.

As will be seen by the accompanying plan, the New Hope Workings embrace a number of independent dykes of the local quartz—topaz lode-rock, which intrude sedimentary rocks of Permo-Carboniferous age, forming part of the Mole Tableland inlier.

These dykes strike from N. 15° to N. 65° E. and vary in thickness from 2 or 3 feet to 25 feet. Though wolfram occurs more or less disseminated, it favours the contact joints principally, so much so, that whereas ordinary stoping *en masse* failed to prove remunerative, tributers, by following the joint fillings, are able to earn a good living.

In some of the workings the lode-rock lies under a cover of the sedimentaries and has been cut at depths down to nearly 100 feet from surface. Some are more or less vertical, others dip rather flatly.

* Ann. Rept. Dept. Mines N.S. Wales, 1906, p. 52.



Govt. Printer.

Cobalt near Torrington.

New Hope Mine (Original Main Workings).

One very persistent line, known as the "Bung Lode," is characterised by a thin joint filling—mostly of crystallized quartz—from 3 to 6 inches in thickness, in which lumps of pure wolfram occur. It has been followed by shafts and shallow cuts from M.L. 20 diagonally through the adjoining M.L. 23, a distance of about 25 chains. Numerous shafts have been sunk along this lode from a few feet to over 120 feet. Some of which—on rich makes, or "bungs," are reported to have yielded up to 35 tons of wolfram concentrates.

Mr. Alfred James, Manager, under date 12th June 1911, states that a large vug occurred in part of this lode, lined with massive quartz crystals with slugs of wolfram adhering to some of them; but the bulk of the wolfram obtained was in the form of loose slugs on the floor of the "pipe" or vug. The largest bunch of ore yielded 12½ tons of pure wolfram, which did not require dressing. Altogether 35 tons came from this bunch, which was followed down 125 feet (the deepest working at the mine); at this depth the lode material was fluor-spar with a little wolfram.

Mr. James states that altogether 90 tons of slug wolfram were obtained from the New Hope property, with about 80 tons of concentrates, in addition, since his connection with it. The previous output is reported to have amounted to 30 tons. A grand total of 200 tons The average percentage of stone crushed is stated to work out at 3 per cent. of concentrates.

Nymagee, 10 miles S.E. A sample of quartz and wolfram from this locality was assayed in 1910, with the following result:—

10-2961—Tungstic trioxide............................ 23 per cent.

Oberon.—In Parish Duckmaloi, County Westmoreland.

Wolfram—in the form of a small loose lump—was discovered here by Messrs. Kirk and Dwyer. A lease of 20 acres was subsequently applied for by the Hon. W. Hurley, M.L.C., but was not surveyed owing to prospecting failing to reveal sufficient inducement to continue.

The occurrence is in granite about 5 miles east of Oberon. During the prospecting carried out under Mr. Hurley, a considerable amount of trenching and cross-cutting was done on the hill where the first discovery was made. A quartz vein, carrying a little wolfram, was located, underlying flatly into the hill; it was opened by a cutting about 40 feet in length, and a tunnel of 30 feet, but the prospects were very poor.

During the surface prospecting on the hill, a 40 lb. slug of pure wolfram and a number of smaller pieces were found, the former being presented to the Mining and Geological Museum.

Payten and Henry's Wolfram Lease.—Cow Flat, M.L. 15, Parish Rock Vale, County Clive. An option over this lease was taken in 1907 by the Elliott Tin Mining Company, Ltd. (J. Mackay, Legal Manager, 125 Queen-street, Melbourne), who put through a trial crushing of 150 tons for 1 ton 4 cwt. 0 qrs. 27 lb. of wolfram concentrates; equal to 0·8 per cent. of concentrates of unstated value. A "bung" or pipe of average ore 14 feet x 14 feet was exposed in the quarry, but operations were suspended in March, 1908.

Pulletop District.—Fifteen tons of wolfram were obtained in this district during 1910.*

Pucka Lode.—Near Yulgilbar. Portion 76, Parish Yulgilbar, County Drake.

A unique discovery of wolfram, associated with sulphide of antimony, was made in 1907 by Mr. T. Bassetti in the Pucka Antimony Mine. It is, however, likely to prove more of mineralogical interest than commercial value.

* Ann. Rept. Dept. Mines N. S. Wales, 1910, p. 57.

The antimony lode strikes N. 65° E., vertical. Opened by four shafts—26, 30, 43, and 53 feet deep—one in a parallel lode 12 feet south-east. The antimony lode varies from 3 to 18 inches in thickness, the ores being stibnite and cervantite, in quartz.

Roberts' Lode.—On south side of M.L. 65, Parish Rock Vale, County Clive; 5½ miles N.W. of Torrington.

Discovered same year as Cow Flat Mine; worked in 1910 by R. Roberts. Quartz-topaz rock, carrying bismuth and wolfram at junction of slate and granite. No regular strike discernible. Opened by numerous shallow trenches and open cuts.

Rockley, Stony Creek.—Wolfram recorded by G. W. Card,* probably from Mt. Stromlo.

Rockvale Wolfram Mines, Limited.—Originally known—on a smaller scale—as the "Wentworth Proprietary," when operating the "Cow Flat" Mine (M.L. 203), now abandoned (which see).

The present Company has a capital of £30,000, in 60,000 shares of 10s. each, H. S. Benjamin, secretary, 51 and 53 Elizabeth-street, Sydney, and holds M.Ls. 18, 19, 20, 34, 68, 90, 91, 95, 101, and 205 (aggregating 338 acres, including machinery and dam sites), in Parish Rock Vale, County Clive.

The leases, battery, and dams are situated on, and adjacent to, the upper portion of Black Swamp, or Bald Rock Creek. The site of the milling and concentrating plant is known as "Tungsten"; the original scene of operations at Cow Flat being known as "Minera."

The Rockvale Company, in addition to unnamed deposits, operates those known after their discoverers, as "Hawkins," "Carter's," "Gibbs," and "Romer's," which are connected by tramways with the reduction plant, and each worked in a face by quarrying or "open cutting," taking all the ore-rock as it comes to the battery.

The reduction plant consists of two units, each of 10-head of 1,250-lb. stamps, dropping 5 inches at the rate of 110 falls per minute. Stamper boxes fitted with wire-wove screens, with 64 holes to the square inch, and Challenge self-feeders.

From the first 10-head the pulp passes direct to two Wilfley tables; the "middlings" from these to two 6 feet Frue vanners; the "tailings" from vanners to settling buddles. Centre "buddlings" allowed to accumulate, then re-treated over the Frue vanners separately.

From the second and latest 10-head unit the pulp, passing through 16 to 25 hole wire-wove screens in the stamper boxes, will run to a 5-hutch May Bros.' jig; "spigots" to a 5 feet Huntington mill with screens of 64 mesh; the mill pulp, after passing through a Spitzkasten, is fed to two Card tables; "middlings" to Frue vanners; "tailings," elevated by 25 feet wheel, pass through blanket-lined launders to discharge.

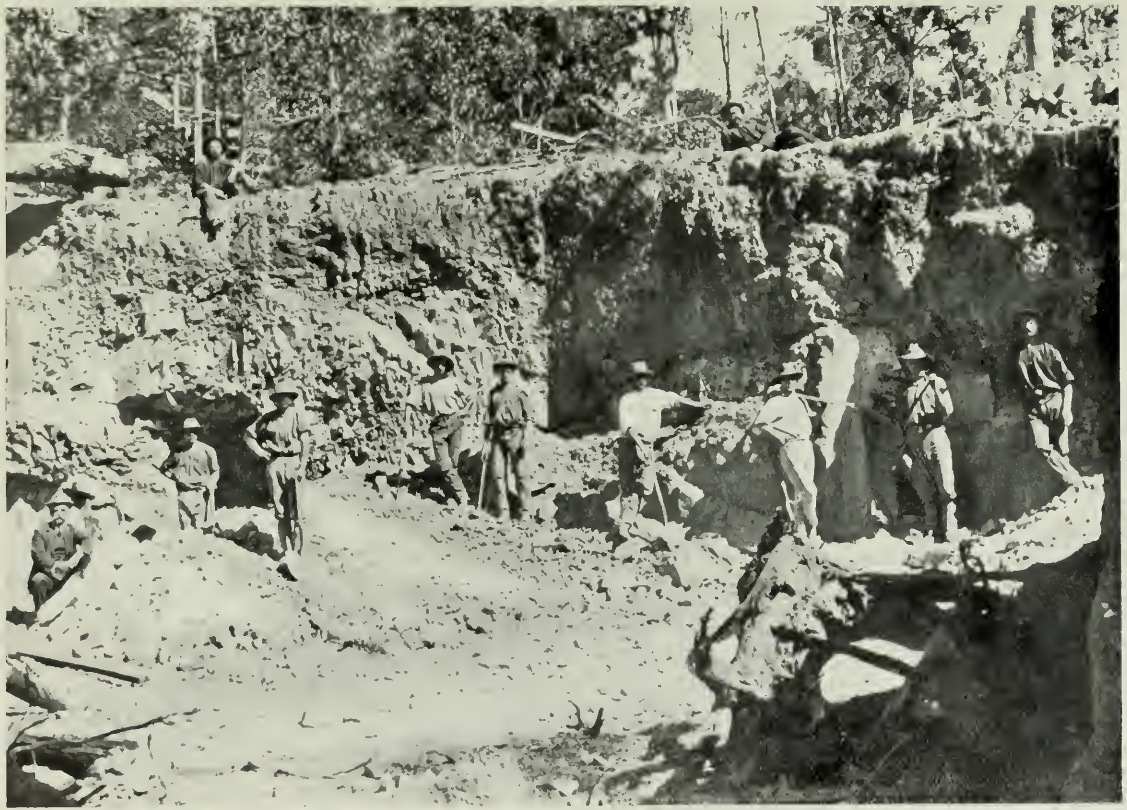
The motive power for battery is obtained by two 35 h.p. Mort's Dock boilers, a 50 h.p. single cylinder horizontal engine, and a vertical engine and 70-light dynamo. Concentration plant driven by 14 h.p. Robey engine.

The breaking plant consists of a May Bros. and a Robey breaker, gauge 1½ inches to 2 inches, with two link-belt elevators to hoppers.

Pumping Plant.—Two pumps, 3 inches and 5 inches, delivering 24,000 gallons per hour.

Water Supply.—Two dams; upper dam, in Black Swamp Creek, used for feed water and concentrating tables.

* Handbook Mining and Geol. Mus., 1902, p. 90.



Mrs. J. Shannessy.

Tungsten near Torrington.

Rockvale Wolfram Company's Main Quarry, Hawkins' Section.

PLATE XIV.

Mrs. J. Shannessy.

Tungsten near Torrington.

Rockvale Wolfram Company's Main Quarry (south-west end), Hawkins' Section.

Ore storage bin, 400 tons capacity; two battery bins, each 100 tons capacity. Trucks hoisted to storage bin. Battery bins filled by link-belt elevator from breakers.

Cost of wood fuel, 8s. per cord.

11-907—Concentrates (average from 11½ tons obtained in March, 1911) from Rockvale Wolfram Company's Mine, Black Swamp:—

Analysis by Mr. H. P. White.

Tungstic trioxide	60·64
Bismuth trioxide	2·16
Manganous oxide	2·65
Alumina	absent
Ferrous oxide	18·21
Lime	0·51
Magnesia	trace
Rare earths of the Cerium group as oxides, Ce_2O_3, Di_2O_3, Y_2O_3, ThO_2, &c.	0·37
Gangue	13·96
Phosphoric anhydride	0·81
Carbon dioxide	0·16
Moisture and undetermined	0·53
	100·00

Fine gold—a few grains per ton.
Fine silver—6 dwt. 13 grs. per ton.

Hawkins's Section, M.L. 20.—The deposits in this lease have been opened by two quarries a short distance apart, and connected with the battery by a tram-line, 40 chains in length.

The mode of working and the occurrence of the lode-rock are illustrated in the accompanying views. The lode-rock in the main quarry dips in the direction of the second, and latest, opening; and will, it is believed, be found to connect with it, as an intermediate shaft cut the lode at a depth of 25 feet.

It is probable that the quartz-topaz lode-rock has the form of an undulating intrusive sheet or sill, the anticlinal folds or rolls of which form the neighbouring outcrops above the sedimentary rocks, owing to removal by denudation of part of the latter.

Close to the main quarry, a shaft sunk during early prospecting operations pierced a porphyritic rock, composed of perfectly symmetrical quartz and felspar crystals, which on exposure fell apart in individual crystals. The quartz is in the form of prisms, with doubly terminated pyramids; the felspar in Carlsbad twins and simple forms.

In the main quarry the lode is intersected by a porphyritic dyke, about 3 ft. 6 in. wide; from the position of the porphyritic rock cut in the shaft, it is probably also intrusive in the lode-rock.

The second principal workings are in *Carter's Lease*, M.L 205, the quarry being 60 chains by tram-line from the battery. Here also the nature of the occurrence and mode of working are well illustrated in the accompanying views; the junctions of the sedimentary rocks with the intrusive lode-rock are also defined.

Haulage from this quarry is by cable wound by a 18 h.p. Robey engine; the lode-rock does not outcrop above the general level, hence has to be followed down by incline track.

Quarries are being opened in contiguous outcrops known as Romer's and Gibbs', in M.Ls. 34 and 101, where good surface indications were obtained by the original prospectors. It is probable that these outcrops may prove to be connected with those in *Carter's Lease*, M.L. 205.

Two or more intersecting dykes of ore-rock occur in this lease, one of which probably connects with the outcrop in Romer's lease (M.L. 101). Gibbs' section adjoins these two leases, but has only been superficially opened by the original prospector in search of rich "slugs" of wolfram. The Company intend opening a quarry and connecting it with the tramway system.

The second crushing and concentrating unit had been given a preliminary trial, but up to the end of August, had not been put in commission, but was shortly expected to be at work.

The total ore crushed in the new plant at Black Swamp to the 2nd September, 1911, amounted (according to Mr. James Fletcher, managing director), to 16,774 tons, from which 112 tons 18 cwt. 2 qrs. of wolfram concentrates were recovered, equal to 0·67 per cent.

Rumsby's Lode.—South-west of the Yankee Tin Lodes, The Gulf, Parish Muir, County Gough.

The richest pipe or bunch of wolfram in the Gulf district occurred in this claim, which consisted of a small triangular area of "left" ground between two other claims, its base measuring only a few feet; yet 27 tons of clean ore was extracted from it, whilst the adjoining claims yielded little or none. The pipe measured 10 feet by 8 feet in its strongest part. The veinstone was chloritic and soft. The wolfram occurred in masses of great purity, accompanied by large bunches of rich green fluor-spar, and lesser quantities of mispickel and copper pyrites. Vugs lined with large quartz crystals were conspicuous.

The pipe was followed to the 120 feet level, the ore becoming poorer with depth; but little prospecting was done, though, according to local report, 6 cwt. of ore were obtained from the bottom of the shaft. The latter, however, is not now available; the nature of the ore-body, bulging in parts, rendered the shaft unsafe as the ore was won.

Several parallel veins occur in the granite, carrying a small proportion of wolfram.

E. C. Andrews states that 12 feet of sinking in Rumsby's Pipe produced 4½ tons of wolfram, of a value of £450, lumps as much as 70 lb. of pure wolfram being obtained.*

Early in 1911 a ton of mixed scheelite and wolfram was obtained from this mine.

Scrubby Gully.—J. Graham discovered wolfram in the usual matrix in March, 1911, between Scrubby and Highland Home Creeks, Parish Highland Home, County Gough, about 2 miles west of M.L. 52 and 1 mile south of Mt. Everard.

Sampson and Cokehill's Lode.—M.L. 21, Parish Ruby, County Buller. Wolfram in small quantity occurs in this lease.

Smith's Mica, and other Lodes.—M.L. 65 and 79, Parish Rock Vale, County Clive, Black Swamp Creek, 5½ miles north-west of Torrington.

It will be seen from the plan that a number of distinct outcrops of the quartz-topaz ore-rock occur in these leases at no distance from the junction of the sedimentary strata. So far only the most superficial prospecting has been done. Recently, however, the leases have changed hands, and active development is likely to ensue in the near future. In each outcrop wolfram and bismuth are discernible.

The lode known locally as the "Mica" lode has been sunk upon for a few feet. Here massive biotite occurs with flaky plates of wolfram, a little

* Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 143.

Mrs. J. Shannessy.

Tungsten near Torrington.

Rockvale Wolfram Company's Quarry (north end), Carter's Section.

PLATE XVI.

Mrs. J. Shannessy.

Tungsten near Torrington.

Rockvale Wolfram Company's Quarry, Carter's Section.

tinstone, and fine acicular crystals of beryl. A green mineral regarded by Mr. Card as probably "torbernite" (copper uranite) occurs in minute quantity, too small for test.

Two small tin lodes occur in M.L. 79, one of which was opened for a distance of about 1 chain to a depth of about 30 feet many years ago; 4 tons of tinstone are reported to have been obtained from it. It strikes N. 35° E. in soft granite. The other lode on the south boundary has not been opened beyond a few feet; tin, wolfram, and bismuth ore occur here in association.

Several of the quartz-topaz outcrops in M.L. 65 are very massive, and could be cheaply worked by quarrying. It is, moreover, highly probable, from the mode of occurrence of this rock, that some of the smaller isolated masses will be found to be connected.

Smyth's Claim.—Near Torrington. E. C. Andrews described this site, which is not at present being worked so far as known, as containing "wolfram and monazite in quartz and pegmatite veins traversing slate near granite. A vertical shaft 80 feet deep has been sunk in a fissure without losing the wolfram. Monazite is associated with kaolin, probably decomposed felspar of pegmatites. At times the pegmatite passes into tight quartz." *

Stalling's Lode.—Sugarloaf Mountain, near head of Wilson's Downfall Creek, about 2½ miles north-west of Wilson's Downfall, close to Queensland border, Parish Ruby, County Buller.

Discovered by G. and F. Stalling in 1892, but not worked until 1907, when it was opened to a depth of a few feet for a yield of about half a ton of wolfram concentrates. It was further prospected by Vosper and party for a length of about 2 chains, and to a depth of 20 feet in places. Six tons of wolfram concentrates are reported to have been thus obtained. The wolfram occurred in bunches at intervals along the lode, which strikes N. 25° E., in aplitic granite, and dips gently S. 65° E. Width from 3 to 6 inches on an average. Several small parallel veins have been superficially prospected about 1 chain east of the main lode, but nothing of importance was discovered. A little molybdenite occurs in one of these.

Sugarloaf Mountain, near Wilson's Downfall.—(See Stalling's Lode.)

Temora, 20 miles west.—A mixed sample of wolfram and cassiterite from this locality was assayed in 1910 for the following return :—

10–1881.—	Tungstic trioxide	41 per cent.
	Metallic tin	19 per cent.

Toohey's Wolfram Lode.—On right bank of Pulletop Creek (also known as Bourke's Creek), Portion 29, Parish Burrandana, County Mitchell.

Discovered by M. Toohey about 1903, and worked intermittently since. Strike N. and S., dip slight to the east; in granite near slate. Opened for about 300 feet in length to a depth of 6 feet. The wolfram occurs in white quartz, and also in the granite walls, as well as loose in clay pug, occurring occasionally in the centre of the lode. The width varies from 3 inches to 2 feet, forming lenses. The wolfram occurs in shoots. The walls are well defined, and micaceous for a thickness of about 6 inches. About half a ton of wolfram concentrates, assaying 68 per cent. tungstic acid, was obtained from the lode to September, 1910. A fair amount of the mineral was shed for a distance of 30 feet from the lode, as the result of weathering and denudation.

* Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 143.

The wolfram appears to cut out in depth, at least so far as followed, though probably other shoots may occur.

About 70 yards east a small quartz vein carries a little wolfram, but not in workable quantity.

Torrington Ore Company, Limited.—Office, 2 Bridge-street, Sydney. Secretary, W. Liggins. Capital, £12,002, in 48,008 shares of 5s. each,

Operating the undermentioned mines in the Parishes of Rock Vale and Highland Home, Counties Clive and Gough. Situated about 7 miles from Torrington Post Office; 23 from Deepwater Railway Station; 382 from the Port of Newcastle; and 490 from Sydney.

Elevation—from 3,600 to 3,700 feet above sea-level.

Mines.			Areas.
"Bismuth" ...	... M.L. 324	......	80 acres.
"Fielder's Hill"	... M.L. 325	......	80 „
„ ...	... M.L. 326	......	40 „
"Wolfram Hill"	... M.L. 28	......	30 „
„	... M.L. 13	......	10 „
„	... M.L. 14	......	8 ac. 3 r. 18 p.
„	... M.L. 8	......	10 acres.
„	... M.L. 9	......	10 „
Battery Site ...	... M.T.	......	2 „
Dam Site ...	... M.T.	......	4 „

The "Bismuth" Mine is situated 21 chains N. 28° E. from the battery; Fielder's Hill, 60 chains N. 3° W; and Wolfram Hill, 160 chains 75° E.

The ore is at present conveyed to the battery in ordinary tip-carts at a daily rate of 13s. per cart, contingent on an agreed number of loads being delivered. It is patent that a considerable saving could be effected by substitution of cable or motor traction.

The "Bismuth Mine"—so named because of the high yield of bismuth—was originally held by Messrs. Brady and Watson, who sold to Messrs. Massey and Brooks, who subsequently formed the above-named Company.

Before the latter decided on a local concentrating plant, 270 tons of ore from this mine were despatched to the Sunny Corner Mine in the Bathurst district, where the first Wilfley table installed in the State was in operation. On the experience there gained in concentrating the wolfram and bismuth product, the present plant at Torrington was designed. It consists of 10 head of 1,000-lb. stamps, dropping 8 inches at 95 falls per minute. The discharge screens are wire-wove, 64 holes to the square inch.

The extreme fragibility of the wolfram ore, even with these coarse screens, is such that 80 per cent. of the concentrates are found to pass through 1,600 holes to the inch; hence the necessity for coarse crushing to avoid undue sliming.

In operation the pulp from the battery is divided between a Card and a Wilfley table; the "middlings," and a slice of "tails" from both, are re-treated on a second Wilfley. The tailings from the Card table and the first Wilfley are elevated by bucket wheel and pass to tailing heap through blanket-lined launders. Tailings from the second Wilfley run into two dead buddles, the "centres" from which are re-treated in a "sweeper" buddle, where a final finished product is obtained of exceeding fineness; almost the

T. H. Nicholas.

Torrington Ore Company's "Bismuth" Mine, showing Junction of Massive Ore-rock with Sedimentary Rocks (in upper left-hand corner of view).

Plate XVIII.

T. H. Nicholas.

Torrington Ore Company's "Bismuth" Mine—Entrance of Inclined Shaft.

whole of it passing readily through a screen of 3,600 holes per square inch. The quality of this final concentrate is shown in the following analysis by J. C. H. Mingaye :—

910—Concentrates from Buddles, Torrington Wolfram Company's Mine.

Moisture at 100 C	0·12
Tungstic trioxide	45·40
Bismuth trioxide	8·26
Bismuth trisulphide	0·60
Copper oxide	minute trace
Manganous oxide	2·52
Cobalt and nickel oxides	0·08
Alumina	trace
Ferrous oxide	12·58
Lime	0·23
Magnesia	0·05
Rare earths of the Cerium group as oxides, Ce_2O_3, Ta_2O_3. Di_2O_3, &c.	3·75
Thoria	0·08
Gangue	24·84
Phosphoric acid	0·85
Carbon dioxide	0·40
	99·76

The absence of tin proved.
Fine gold—3 dwt. 6 grs. per ton.
Fine silver—1 oz. 0 dwt. 16 grs. per ton.

The composition of the concentrates obtained from the Card and Wilfley tables is shown in the accompanying analysis by J. C. H. Mingaye of a sample taken by the Writer on the 24th March, 1911, from the cut-off launder :—

911—Concentrates from tables, Torrington Ore Company's Mine.

Moisture at 100 C	0·12
Tungstic trioxide	56·00
Bismuth trioxide	11·16
Bismuth trisulphide	1·45
Copper oxide	trace
Manganous oxide	3·61
Cobalt and nickel oxides	0·07
Alumina	trace
Ferrous oxide	16·39
Lime	0·57
Magnesia	0·05
Rare earths of the Cerium group as oxides, Ce_2O_3, Di_2O_3, Y_2O_3, &c.	2·62
Thoria	0·05
Gangue	7·19
Phosphoric acid	1·01
Carbon dioxide	0·10
	100·39

Fine gold—4 dwt. 8 grs. per ton.
Fine silver—13 dwt. 11 grs. per ton.

The concentrates contained a quantity of particles of metallic iron, which were carefully taken out of the sample prepared for analysis.

The finished product bagged for market is carefully sampled and brought up to grade when necessary.

The tailings as finally discharged from all sections are represented by the following analysis of an average from 200 holes, sunk in the tailings heap on behalf of the Company:—

11–912—Tailings from the Torrington Ore Company's Battery.

W. A. Greig, Analyst.

Insoluble in acids (gangue)	95·71
Tungstic trioxide	0·94
Ferric oxide and alumina	1·89
Lime	0·50
Magnesia	0·11
Total water	0·56
	99·71

No bismuth detected.

Composition of gangue—

Silica	88·28
Ferric oxide and alumina	8·82
Alkalies, and undetermined	2·90
	100·00

From each of the Company's mines rich bunches of pure wolfram are occasionally obtained. The Bismuth Mine, in particular, has yielded solid masses of considerable weight, one from the earlier workings weighing 3 cwt. The composition of one of these is shown in the following analysis by H. P. White:—

11–909—Pure Crushed Wolfram from Torrington Ore Company's Bismuth Mine.

Tungstic trioxide	70·73
Ferrous oxide	18·13
Manganous oxide	3·64
Lime	1·64
Magnesia	trace
Gangue	5·55
	99·69

No tin, bismuth, or rare earths of the Cerium Group detected.

The proportion of manganous oxide compared with ferrous oxide in the samples tested, seem to place them nearer "ferberite" than "wolframite."

Smaltine (arsenide of cobalt, nickel, and iron) occurs in the Bismuth Mine; a typical sample yielded the following results:—

11–949—Arsenical ore, with biotite, from the Torrington Ore Company's Bismuth Mine, Torrington.

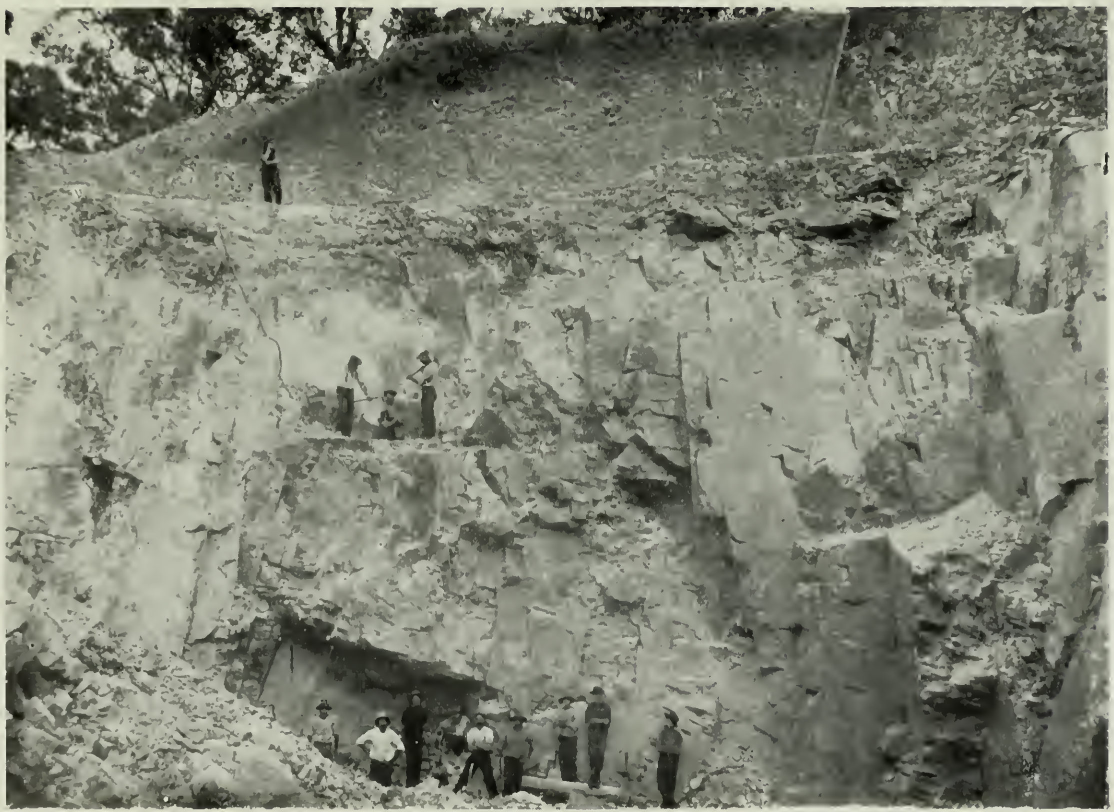
Analysis by W. A. Greig.

Arsenic	31·69
Bismuth	0·60
Lead	trace
Tin	absent
Cobalt	6·15
Nickel	2·31
Iron	11·55
*Alumina	8·86
Lime	1·35
Magnesia	0·67
Sulphur	0·38
Gangue	31·40
Oxygen, and undetermined	5·04
	100·00

Fine silver at the rate of 7 dwt. 15 grs. per ton.
,, gold ,, ,, a trace (under 1 dwt. per ton).

* Including any phosphoric anhydride or titanium dioxide present.

Junction of Sedimentary Rocks........→



T. H. Nicholls.

Torrington Ore Company's Fielder's Hill Quarry (north end).

T. H. Nicholas.

Torrington Ore Company's Fielder's Hill Quarry (south end).

Bismuth Mine.—The position of this mine in 1904 is thus described by E. C. Andrews:—

" *Occurrence.*—Wolfram and bismuth in greisen and pegmatite at junction of fine-grained granite, with spotted slates. Strike of the "quartz (greisen) blow" is about N.W. and S.E. In length it exceeds 100 yards, and in width about 15 yards.

" *Workings.*—The lode is opened up along some 100 feet of outcrop. An open cut was formed from which two shafts have been sunk, connected with each other (by sloping drives) at a depth of 75 feet. One of the shafts is in form of a cut driven diagonally across lode.

" *Minerals.*—Wolfram, native bismuth, and sulphide of bismuth. *Gangue*—Fluor-spar, quartz, greisen, pegmatite, emeralds (beryls), biotite, monazite, and topaz (?). In the tight, solid quartz containing little or no admixture of mica, very little wolfram occurs; but in the strings and bunches of pegmatite (coarse vitreous quartz, large white and pink felspar, masses of biotite, with beryls, monazite, &c.), which occur throughout the greisen mass, the wolfram is specially plentiful in large squarish and friable pieces. One piece raised exceeded 300 lb. in weight. The bismuth generally has a similar habitat to that of the wolfram. The wolfram not occurring in true fissures, and being scattered through the branching pegmatites, is more or less patchy in character. At the lowest workings, however (75 feet), it is just as pronounced as at the surface, and there is every indication of its continuation to a much greater depth."*

In 1911 the ore-body was still going strong under foot and maintaining its metallic values. The incline shaft had reached 300 feet from the surface. The inclination of the first 200 feet being about 31°, of the last 100 feet, about 35°. The vertical depth at the face being about 150 feet.

The richness of this lode in both tungsten and bismuth, enables the Company to maintain standard grades for their wolfram-bismuth concentrates, by admixture of proportional tonnage in their crushing supply.

Fielder's Hill, in M.L. 325, is a small prominence formed by an outcrop of the quartz-topaz ore-rock intruding the sedimentary series. Its original appearance is shown in the accompanying photograph taken by the mine manager—Mr. T. H. Nicholas—before mining operations began.

The later views of the quarry faces (the most extensive in the field) were also taken by the same gentleman and reveal the mining aspect in April, 1911, the length of the quarry being 150 feet, and the width about 70 feet.

The present quarry face at the north end is about 42 feet deep in solid ore-rock. The overburden of Permo-Carboniferous claystones, sandstones, and conglomerates, is clearly shown in this view; the miner on the upper ledge standing on the junction of the two formations.

The quarry is approached by a cutting from the west, from which an incline shaft has been sunk to the level of the present bottom of the open workings, through which the ore is raised to the truck line level, by a winch. The loaded trucks are run by hand to a breaker of 8 tons per hour capacity, driven by an 18 h.p. engine; the broken stone being delivered from the breaker into the ore-bin, from which the carts are loaded.

In the bottom of the quarry, about 35 feet back from the face, in March, 1911, a large mass of the sedimentary rocks was exposed; the contacts with the ore-rock affording most instructive illustrations of the shattering and intruding character of the latter; several sections to scale being introduced in this work.

* Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 143.

Though a large amount of the exposed ore-rock at times reveals little wolfram, yet a shot at any time may expose vugs with rich bunches of both wolfram and bismuth, the latter in the form of carbonate and oxide generally.

The interesting occurrence of a pipe-like mass of pure kaolin in this quarry has already been described; though at its upper level nearly 12 feet in diameter, it tapers to a couple of feet at the bottom of the quarry. Its composition has been determined. (See p. 42.)

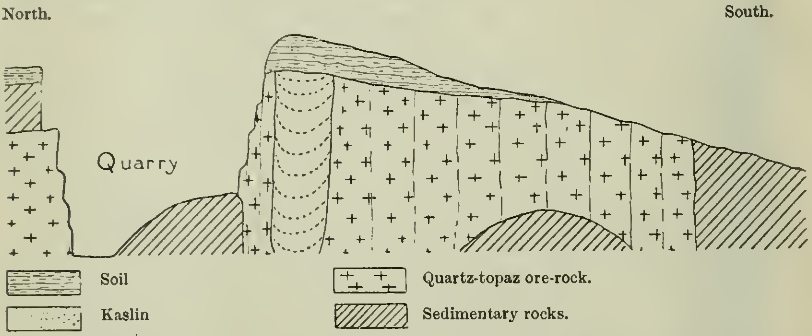


Fig. 7.—Section across Fielder's Hill Quarry. M.L. 325, Torrington. Scale 40 ft. to an inch.

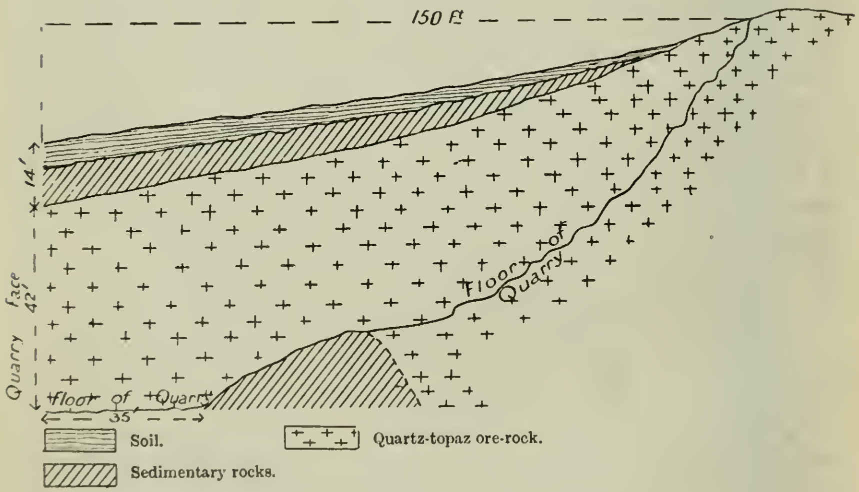


Fig. 8.—Longitudinal section, Fielder's Hill Quarry.

The Wolfram Hill workings are in M.Ls. 8 and 28, Parish Highland Home, County Gough.

Wolfram Hill also owes its prominence to the superior resistance to weathering offered by the quartz-topaz ore-rock—compared with the surrounding sedimentary rocks.

This deposit has been opened by three shafts—the deepest 50 feet, and open trenching for a distance of about 130 feet. The workings are

PLATE XXI.

T. H. Nicholas.

Original Outcrop of Fielder's Hill Wolfram and Bismuth Ore-body.

connected along a junction of the two formations where rich ore made in bunches. Only these richer makes were followed, as the ore had to be carted 2 miles to the battery. Work has at present ceased in this section.

In M.L. 8 adjoining, a trench 250 feet long, 10 feet wide, and about 10 feet in depth, has been cut in a lode striking in the direction of Wolfram Hill, and bounded by conglomerate and claystone. This opening is known as the "Bismuth End," because of the predominance of that metal.

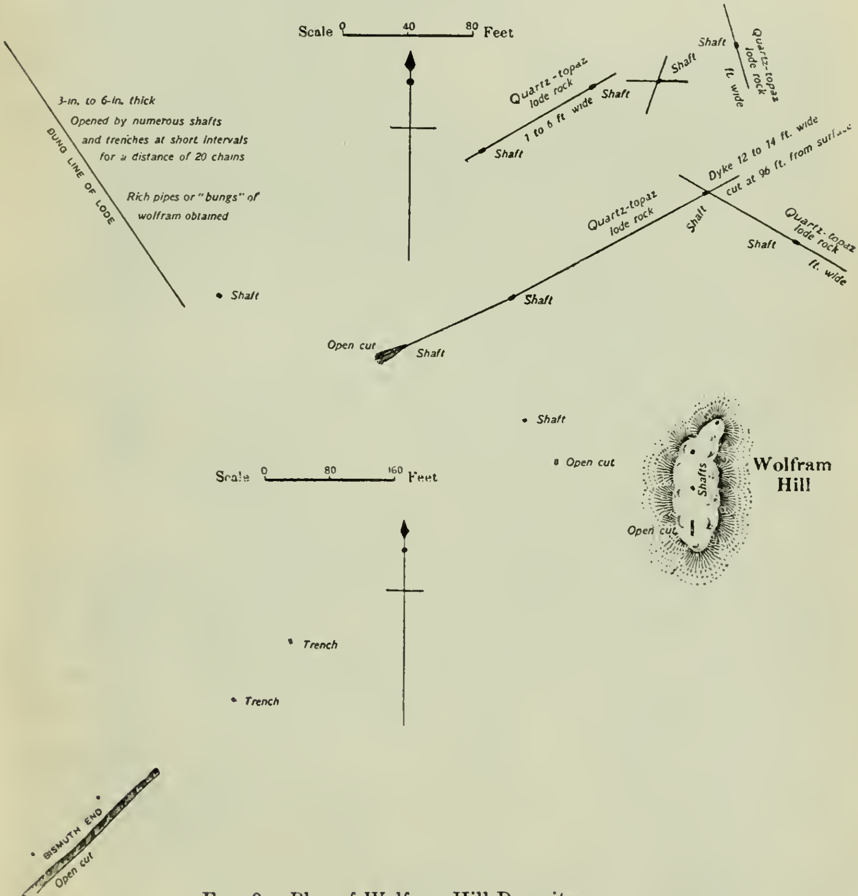


Fig. 9.—Plan of Wolfram Hill Deposits.

The following particulars of output have been kindly supplied by the Torrington Ore Company :—

Old mine ("Bismuth"), from 1904 to 31st July, 1911	...	24,581	tons of ore.
Fielder's Hill	,, ,,	...	23,724	,,
Wolfram Hill	,, ,,	...	1,956	,,
Prospecting shows	,, ,,	...	555	,,
			50,816	,,

Yield in concentrates to 31st July, 1911, 638 tons, of a value of £87,840.

The Broken Hill Block 14 Mining Company, after nearly six months testing of the Fielder's Hill deposit by diamond drill boring, has recently exercised an option to purchase the Torrington Ore Company's interests. A new company of 150,000 shares of 20s. each is being formed to carry on operations on a large scale.

Torrington Wolfram Proprietary, Limited.—M.Ls. 10, 55 to 59, 60, 61, 64, 70, 75 to 77, 81, 83, 84, 87, 92, Parishes Rockvale and Bates, County Clive. G. P. Lock, Citizens' Chambers, Newcastle.

On east side of Black Swamp Creek, opposite Rockvale Wolfram Mines, Limited, 4 miles from Torrington Post Office, and 20 from Deepwater Railway Station.

At present working—by quarrying—in M.Ls. 70 and 75, which are connected with the battery by tramways 20 and 56 chains in length.

Dam sites for additional water supply secured on Bobs and Green Swamps; main supply from Black Swamp Creek, adjacent to battery.

The reduction plant consists of a Krupp ball mill—wet crushing—of a capacity up to 100 tons for twenty-four hours.

Mill fitted with wire-wove screens, 144 holes to the square inch; and fed automatically by percussion feeders.

Mill pulp to pass through classifier to two Krupp tables, "middlings" to Ferrari's tables. Concentrates from all tables to one 4-foot Frue vanner, as with present low-grade ore unable to take cut of clean concentrates direct from tables; this will follow with higher grade ore.

Plant driven by suction gas, firing a 62-break h.p. engine.

A 15-kilowatt generator supplies current for driving tables, pumping water supply, draining mines, and for electric lighting.

The suction gas is manufactured in the Economic Gas and Power Company's Dowson Plant (London), charcoal for which is made in a patent circular retort, 7 feet diameter, by 9 feet in height, made of ordinary steel plate unlined; capacity, two cords of billets, not exceeding 9 inches diameter. Time for green wood, twenty-four hours per charge; dry wood, thirteen to fifteen hours. Charcoal delivered in trucks from retort to store adjacent to producer. Eight cwt. of charcoal and two-thirds of a cord of wood used in each ten-hour shift, for all power purposes.

Ore from the quarries in M.Ls. 70 and 75 is delivered by horse-traction tramway (with loop at delivery end) on to an 8-feet grizzly, set at 1½ inch. The floor of the latter is level with rock-breaker, into which it is shovelled.

The Krupp rock-breaker—15 inches x 9 inches—has a capacity of 8 tons per hour to 1½ inch. gauge. The broken ore falls down shoot to elevator boot, thence elevated to 90-ton ore bin.

When examined in March, 1911, the concentrating plant had not been long running, and additions in the way of classifiers and extra tables were contemplated for more efficient working.

Unfortunately the hunch-plates of the Ball mill gave out in May, and the spares ordered from Germany proved too large. At the beginning of August the mill was still "hung up."

The grade of the ore quarried at the beginning was exceedingly low, not averaging more than about 3 lb. of concentrates to the ton; at the date mentioned, the yield had increased to 9 or 10 lb. to the ton, a percentage too low

Mrs. J. Shannessy.

Torrington Wolfram Proprietary—Entrance to No. 1 Quarry in M.L. 70 and Tram-line to Battery.

Mrs. J. Shannessy.

Torrington Wolfram Proprietary, Ltd. No. 1 Quarry in M.L. 70.

for profitable working. As some richer deposits close to the batttery have been partially tested by shaft, it would be wise to develop these and use the higher grade ore to sweeten the output from the quarries.

Quarries 70A and 75A afford most instructive evidence of intrusive contacts, as will be seen in the following sections.

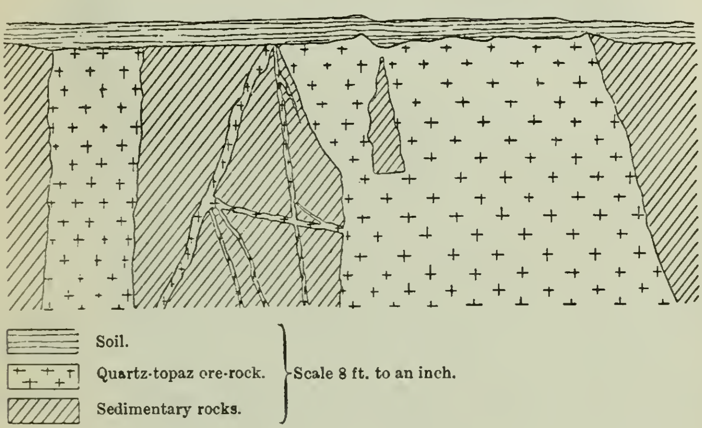


FIG. 10.—Section in quarry in M.L. 75A, showing intrusive contact. Parish Bates, County Clive. Torrington Wolfram Proprietary, Ltd.

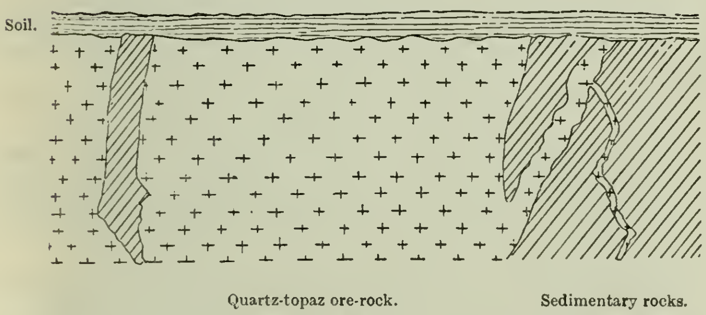


FIG. 11.—Section in quarry in M.L. 75A. Parish Bates, County Clive. Showing intrusive contact. Torrington Wolfram Proprietary, Ltd. Scale 8 ft. to an inch.

Quarry 75C exhibits excellent instances of "rolls," or undulations of the intrusive sill of ore-rock, as it pitches down under the sedimentaries and again rises to the surface a short distance away.

The composition of the concentrates obtained from M.L. 75 is shown in the following analysis, which reveals more the constitution of ferberite than wolframite:—

11/908.—Concentrates from M.L. 75, Parish Bates, County Clive, Black Swamp, Torrington Wolfram Proprietary.

Analysis by Mr. W. A. Greig.

Tungstic trioxide	58·51
Bismuth trioxide	4·82
Manganous oxide	2·10
Alumina	absent
Ferrous oxide	13·61
Lime	0·60
Magnesia	absent
Rare earths of the Cerium groups as oxides Ce_2O_3, Di_2O_3, Y_2O_3, ThO_2, &c.	0·14
Phosphoric anhydride	0·42
Carbon dioxide	0·34
Gangue	19·77
	100·31

Fine gold—3 dwt. 6 gr. per ton.
Fine silver—4 dwt. 8 gr. per ton.

During operations 15 tons of concentrates were obtained, according to Mr. G. P. Lock, which averaged 59·5 per cent. of Tungstic oxide, and 6·5 per cent. of bismuth.

Trewhella's Lode.—Near north-east corner of M.L. 47, Parish Bates, County Clive.

Discovered by John Trewhella in April, 1910. Striking N. 35° E. in porphyritic granite. Opened by a shaft 12 feet deep, and two shallow trenches, the extreme openings being about 140 feet apart. Width of lode about 2 feet 6 inches, though the lode formation is reported to run to 8 feet.

Wolfram and bismuth occur in association; the richest portion of the latter is confined to about 1 foot in width in centre of lode.

From the shaft and trenches 1 cwt. 3 qrs. of wolfram, assaying 70 per cent. tungstic oxide, was obtained; and 150 lb. bismuth ore, assaying 50 per cent. metallic. The bismuth realised 3s. 6d. per lb., and the wolfram at the rate of £102 per ton.

Uren's Claim.—Near Torrington. E. C. Andrews describes this site in 1904 as a—

> "Large quartzose greisen 'blow,' exceeding 120 yards in length, crossed with irregularly-shaped masses of vitreous quartz and pegmatite containing friable wolfram. Type same as its neighbour, Kate Mine. The occurrence is in conglomerates and spotted slates near granite. One shaft is 25 feet deep."*

Wagra.—Portions 181, 191, 192, Parish Wagra, County Goulburn. Messrs. Collingridge Bros. on the 2nd February, 1911, reported discovery of a wolfram-bearing lode running through these portions in rugged country. Samples forwarded to the Department consist of tabular wolfram in quartz.

Warren's Lode.—About 2 chains north of, and parallel to, Davison's Lode, The Gulf, Parish Muir, County Gough.

Opened to about 20 feet. Veinstone chloritic, with fibrous hornblende.

Waukeroo, Barrier Range.—Wolfram has been reported from this locality, but particulars are not available.

Welcome Stranger Mine, area 4 acres.—On north boundary of Portion 92, Parish Rock Vale, County Clive.

* Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 143.

Mrs. J. Shannessy.

Torrington Wolfram Proprietary, Ltd. No. 2 Quarry M.L. 75.

Mrs. J. Shannessy.

Torrington Wolfram Proprietary, Ltd. Quarry in M.L. 75.

Opened about the middle of 1910 by Myers and McMullen. Shaft 24 feet deep in August. About $4\frac{1}{2}$ tons of wolfram in coarse lumps extracted. At date of inspection in August, 1910, a large block of pure wolfram was showing at bottom of shaft. The mineral occurs in chlorite and quartz in aplitic granite. In March, 1911, the ore-shoot had been followed to 46 feet in picking ground, the total output reaching $14\frac{1}{2}$ tons of high-grade wolfram—the largest block weighing 75 lb.

Wilson's Downfall Ideal Mine.—A little wolfram occurs in this mine in platy form in quartz.

Wentworth Mining Properties, Limited.—Minera, near Torrington. (See Rockvale Wolfram Company.)

Wentworth Claim.—Cow Flat. E. C. Andrews, in 1904, described this mine as follows:—

> "Occurrence—Wolfram in irregularly-shaped quartzose greisen at contact of slate and granite. Outcrop from 5 to 10 chains in length, about 10 feet in width.
>
> "Workings—Three prospecting shafts: eastern one, 51 feet deep; middle, 75 feet (with several cuts); western, 51 feet (cross-cuts). The minerals are wolfram and monazite. *Gangue*—Quartz, with traces of felspar and small percentage of white mica. The wolfram is fairly evenly scattered through the granular to tight quartz, in square friable pieces not at all tabular, as at Wilson's Downfall.
>
> "Machinery—Mr. Hartwell Conder, A.R.S.M., is at present erecting a plant to treat the wolfram. A tramway, some three-quarters of a mile in length, will deliver the ore into hoppers, the same feeding a rock breaker. Trommels, rolls, and jiggers will be employed to save the mineral."* Afterwards removed to Black Swamp.

Wild Kate Mine.—Near Torrington. The position of this mine in 1904 is described by E. C. Andrews as:—

> "A large granular greisen 'blow.' Worked by means of open cuts and shafts. Irregular masses of pegmatite (large dark vitreous quartz, felspar, and black mica) branch repeatedly through the 'quartz blow.' In these bunches occur large stout crystalline masses of friable wolfram."†

Yalgogrin.—Wolfram reported to occur 20 miles west of Yalgogrin, but no particulars known.

Yulgilbar.—(See Pucka Lode.)

* Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 143. † Ann. Rept. Dept. Mines N. S. Wales, 1904, p.

VIIa.—SCHEELITE DEPOSITS.

Adelong.—Scheelite from Victoria Reef Gold Mine, County Wynyard, was recorded by Professor A. Liversidge, M.A., F.R.S., as "massive, but with a portion of a crystal showing on one side, of an amber colour, translucent, resinous lustre, brittle, splintery fracture, hardness 4–5; specific gravity, 6·097. Associated with a dark green chloritic veinstone.

"The following analysis was kindly made for me by Dr. Helms:—*

Loss at red heat	·25
Tungstic acid	79·53
Lime	19·14
Alumina	·58
Magnesia	·07
	99·57

Alick Steyne Creek.—Parish Highland Home, County Gough. G. W. Card records scheelite and wolfram from this locality.†

Barraba and Manilla (between).—Scheelite recorded in Portions 34 and 35, Parish Wilson, County Darling.

Berridale.—Parish Coolamatong, County Wallace. G. W. Card records scheelite (red variety) associated with quartz from this locality.‡

Binley and Son's Mine.—Portion 109, Parish Metz, County Sandon, adjoining Portion 58, the workings between the top lode and the latter site being a more or less continuous line of shallow shafts, on a strike of N. 80° W. The new shaft on edge of fall is down 50 feet, with a little scheelite and antimony showing. The others range to 60 feet in depth. Several small rich lenses obtained along the course of the lode.

According to Mr. E. McNamara, Bingle and Son, since February, 1911, have raised:—

	ton	cwt.	qrs.	lb.
Antimony	1	16	1	4
Scheelite	0	12	2	12

From the same portion the Advance Syndicate, since March, 1909, raised the following ore, according to the same authority, the deepest working level being 180 feet:—

	tons	cwt.	qrs.	lb.
Scheelite	27	13	3	2
Antimony	44	10	2	4

Bull-frog Lode.—M.L. 80, Parish Metz, County Sandon. Hillgrove.

Discovered and held by F. H. Gibson, who followed a trail by "loaming" up the slope from Swamp Creek, probably the first application of this method of prospecting to scheelite.

Discovered in May, 1910; opened in August of the same year. Shaft down 50 feet in May, 1911. Driven north 19 feet, and south 30 feet, at the 40-foot level.

In this level three principal lenses occur, the longest 21 feet. Two tons being taken from the largest lens, 1 ton 5 cwt. from the next. The width varies from 1 to 10 inches. The lode strikes N. 10° W., and is almost vertical, in granite; the ore continues in roof and floor of level.

The output to date of 18th May, 1911, amounts to 4 tons 7 cwt. 2 qrs. 15 lb.

* Min. Products N. S. Wales, 1882, p. 104. † Records Geol. Survey N. S. Wales, 1907, VIII, Pt. 3, p. 3.
‡ *Ibid.*, 1909, VIII, Pt. 4, p. 275.

The "firsts" average about 72 per cent. of tungstic oxide. The "seconds are estimated to yield about 4 per cent. About 12 tons of the latter await treatment at the local battery and concentrating plant.

A sample of the first concentrates in hand on the 18th May, 1911, yielded on assay :—

11-1499—Tungstic acid .... 73·55 per cent.

The proprietor has fitted up a compact "bucking" table, faced with a granite slab set in clay and cement, framed with wood. (See p. 24.)

In the freehold (Portion 15) adjoining, Mr. Gibson had previously discovered three other lines of lode carrying short shoots of scheelite, from which he obtained £89 worth of clean mineral. From one—a white quartz reef—a block of scheelite 5 inches in diameter yielded £20 11s. 6d. worth of ore in 8 feet of sinking, then cut out.

Bowling Alley Point.—(See Nundle.)

Brown's Creek (Lewis' Creek).—Scheelite.

Carri, Upper Macleay District.—Mr. R. Holmes, 71, Thompson-street, Darlinghurst, reported to the Writer a lode containing scheelite 8 inches wide at Carri.

Centennial Scheelite Mine.—Hillgrove. G.L. 224, Parish Metz, County Sandon, now held as a mineral lease. Area, 10 acres. Held by the Centennial Syndicate, the site being originally known as the Centennial Gold Mine, situated on west side of Baker's Creek Gorge.

Worked for scheelite by E. Davis and John Cuff, when the mineral was worth only about £12 per ton locally. About 20 tons are reported to have been obtained at this date.

H. G. Maddricks and J. Townsend entered into possession about 1899, and raised 8 tons in six months. Subsequently E. Davis and W. Young raised 15 to 20 tons from it. During these operations the ore was packed to the top of the tableland for dressing.

Since 1903 Maddricks has worked the lode intermittently.

The total output to May, 1911, is estimated by the latter to be about 70 tons.

The lode strikes nearly N. and S., and dips east; in gneissic granite. It has been opened by tunnels to a depth of about 250 or 300 feet below the highest outcrop, and a lower tunnel is now being driven about 80 feet below the deepest workings on ore. The principal lens (Davis') is expected to be cut at 260 feet from the entrance. This lens had a horizontal length of 25 feet in the upper workings, and a thickness varying from a streak to 1 foot, containing high-grade ore, a solid 3 cwt. block being obtained in one spot, and as much as 1 ton in a shift.

The lowest tunnel was in 160 feet in May, 1911, and a connection made by winze following a short shoot from the next upper level. Very little ore is at present being won whilst driving, the lode fissure forming a "roll," owing to protuberance of a hard boss of country from the footwall. It is thought that better prospects are likely when the lode channel returns to its normal dip, but the main ore-shoot (Davis') is not expected for at least another 100 feet of driving.

In M.L. 30, adjoining, scheelite has been obtained in a lode cut by a cross-cut tunnel driven by the old South Hopetoun Gold Mining Company many years ago. The tunnel was driven for the purpose of intersecting an antimony lode, which was reached in about 300 feet. A lode carrying scheelite was cut before the antimony lode was reached. About 25 tons are reported to have been obtained in driving along it, and overhead stoping for a few feet. This site is now known as the Mountain Maid Lode, a 2-acre lease being applied for to cover it.

Cranston and Party's Mine.—Curry's Lode, Hillgrove. P.M.L. 5, of 1 acre, with 4 acres P.M.L. 7 on the underlay, with which the former, is being amalgamated. The lease is situated in freehold, Portion 116, Parish Metz, County Sandon, close to the Baker's Creek Falls.

This is a well-defined lode in porphyritic granite, striking about N. 55° W., and underlying N. 35° E., at about 61° in Cranston's lower workings. The lode has been worked at intervals for a considerable distance to the south eastward, several parallel lines occurring in close proximity. In places it is associated with stibnite (antimony sulphide). The scheelite occurs in small lenses and thin veins, with frequent blanks in the channel, both horizontally and vertically.

Cranston and party are mining the lower extension of what was originally known as Curry's Lode at surface. By sinking a vertical shaft this lode was cut at Curry's boundary 10 feet back from the shaft at the 140 feet level. The shaft was continued until the lode was intersected, which was then followed on the underlay to the present depth of 260 feet by the shaft, or about 300 feet from the surface following the lode.

The present shoot of ore lies north-west of the shaft, and has a horizontal length of 16 feet, with an average thickness of scheelite of 3 to 6 inches, varying from a thread up to 18 inches in the widest, of mixed ore and country.

At the 140 feet level a level was driven north-westerly for some distance, ore occurring intermittently for a length of 40 feet.

Curry's Lode has yielded a considerable amount of scheelite, but the output from the earlier workings cannot be ascertained. From the lower portion Cranston and party have obtained, from 17th March, 1908, to 18th May, 1911, a total of 54 tons 3 cwt. of dressed scheelite, according to one of the party, Mr. J. Matson, who kindly supplied the information.

Damifino Lode.—Hillgrove, M.L. 31, Parish Metz, County Sandon. Outcropping on east side of Baker's Creek, on steep fall.

Originally opened by G. Coss and J. Elsmere about 1895, who are reported to have extracted about 13 tons of scheelite.

Secured by James Usher and party in 1904. Now being worked by the Damifino Syndicate.

Opened to a depth of 150 feet by shaft. No driving. Length of shoot from 2 to 10 feet; average width, 3 to 4 inches, varying from an inch to 9 inches. Associated in parts with stibnite.

The syndicate in May, 1911, was driving a low-level cross-cut tunnel, under aid from the Prospecting Vote, to intersect this lode about 230 feet below the present working level in the shaft.

Three other parallel lines of lode have been discovered closely adjacent, which will be intersected in the crosscut tunnel. One of these, containing mixed scheelite and antimony, reported to be 14 to 22 inches wide, has been opened to a depth of 42 feet. Now that low-grade mixed ores of this character can be concentrated locally, it is thought that this lode will prove remunerative. Another lode has been located north-east of the shaft—at no great distance.

The steep fall of the country between the outcrops and the creek affords an admirable site for tunnelling. Thn present low-level tunnel is expected to reach the main lode in 300 feet; on the 18th May, 1911, it was in 110 feet. (See also Usher's Lode, p. 86.)

Frogmore.—Burrowa district. A little scheelite with wolfram occurs 4 miles east of Frogmore, on Reid's Flat road, M.L. 70, Parish Alton, County King.

Geddes Estate.—Fifteen miles from Manilla, and 1½ from Crow Mountain road. Scheelite lode opened about 1908 to a depth of 50 feet in slate country; 12 tons of lode stuff crushed for 3 cwt. of concentrates, assaying 68 per cent. tungstic acid.

Gilgai.—In 1906 it was recorded that grains of scheelite occurred in the tin drift under basalt, probably in Percy's Lead on north boundary of Portion 407, and running through Portions 335, 420, 157, and M.L. 230, Parish Clive, County Gough, about 1½ miles south-east of Gilgai.

Hillgrove District.—Scheelite was noted at Hillgrove shortly after the most important gold discovery, about 1887. E. C. Andrews, writing of the discovery of scheelite at Hillgrove, states :—

> "The finding of high-grade scheelite near the town in the coarse granite is interesting, inasmuch as, so far, very few similar occurrences have been reported from New South Wales.
>
> "The ore is confined to small lenticular patches in veins. The principal suppliers of the mineral are Keys and party, Maddricks and party, the Hopetoun, and Wade's party, near Brackin's Spur. Over 70 tons of scheelite were put into the market for the year ending December, 1899. Most of the ore was of good quality, varying from 50 per per cent. to 60 per cent. of tungstic acid. Ten shillings per unit was paid for ore over 60 per cent. Keys and party, from two blocks, supplied 20 tons; Maddricks and party, about 15 tons; Snow and Son, about 15 tons; Willmott and Company, about 20 tons. Most of this has been won during the half-year ending December, 1899." *

Hillgrove Four-mile Scheelite Claim.—On the Metz side of the Falls, near the junction of the Four-mile and Baker's Creek, 2½ miles southerly from Hillgrove, opposite Whittaker's Spur, Parish Metz, County Sandon.

Quartz reef with scheelite in granite. Strike N.N.W. Opened by shaft to 23 feet, and tunnel 52 feet. Vein from 1 to 2 inches thick, showing good scheelite in places. Aid granted from the Prospecting Vote to sink 50 feet winze from tunnel level (P.B. 02-3,330). No further report.

E. C. Andrews describes a scheelite lode on top of Falls, north of Eleanora Reef at contact of granite and slate (not now worked) in the following terms:—

> "The reef is in granite, with a strike N.N.W., and at right angles to the igneous and sedimentary contact. It has been proved for some 400 yards along the surface. It cuts into the slates, accompanying a granite tongue. The occurrence appears to be a true fissure. Workings along outcrop rarely exceed 20 feet in depth."†

Hillgrove.—Back of Hospital and Snow's Dam, 1¼ miles north of Baker's Creek Gold Mine, Parish Metz, County Sandon.

In 1908, Inspector Carthew reported, in connection with an application for aid from the Prospecting Vote, that a quartz vein striking N.W. in granite had been opened by several shafts from 20 to 50 feet in depth, and trenching and open cutting. About 70 tons of scheelite were reported to have been won, in 1898-9, from the latter, but owing to floodings filling the superficial openings, these were not available for inspection (P.B. 08-880).

Hillgrove.—Two miles north of Baker's Creek Gold Mine, on east side of Gorge, near Snow's Dam, Parish Metz, County Sandon.

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* Mineral Resources No. 8. Rept. on the Hillgrove Gold-field, 1900, p. 10.
† Ann. Rept. Dept. Mines N. S. Wales., 1904, p. 142.

In 1900, Inspector Carthew described this occurrence as a reef 6 inches wide in granite, and carrying scheelite. Strike N. 20° W.; dipping at 70° from the horizontal. Aided to sink from 8 feet to 50 feet following the vein. (P.B. 00–3,221). No further report.

Hopetoun Reefs, Hillgrove.—E. C Andrews describes these well-known reefs as occurring:—

"In a very gneissic and crushed granite near a block of included slate, three reefs exist, having a parallel disposition. A long tunnel has been driven in the hillside near the creek (Baker's) level, with cross-cuts therefrom to exploit the reefs. The filling is for the most part crushed country, very little quartz occurring. The ores are gold and scheelite. The values decrease decidedly with depth. At depths of 300 and 400 feet small patches of 'ivory' scheelite may be seen apparently scattered capriciously throughout the vein material."†

"The property containing these reefs was taken up by a company of 100,000 £1 shares. It was known at first as the 'Root Hog.' Afterwards, various names, such as the Earl of Hopetoun and Lady Hopetoun, were given to different portions of the property. At present all the blocks constituting the old gold leases have been amalgamated into one property—the New England Scheelite property.

"The workings on the reefs are confined solely to the coarse granite area. The reefs approximate closely in both strike and dip to the more important lodes of the Hillgrove gold-field. Of recent years the gold of the reefs has been found to give place, in patches, to masses of scheelite. In the upper portions of Nos. 1 and 2 lodes the scheelite was of very good quality. Mr. Fuller, of Hillgrove, informs me that at a depth of 300 feet below the surface a large body of low-grade lime tungstate has been exposed in places as much as 3 feet wide.

"Both gold and scheelite have been won by means of tunnels driven into the hillside.

"No. 1 tunnel, 20 feet above the creek, bears 15° north of west, and is 1,176 feet long. About 400 feet from the mouth of the tunnel No. 2 reef was cut. This has a strike of 35° north of west, and is thrown some 5 feet to the south by a cross course near the point of intersection with the tunnel.

"A little further along Nos. 1 and 2 reefs have been stoped for a width of 20 feet, a height of about 50 feet, and a length of 60 feet.

"In the chamber so formed machinery was set up for the sinking of a main underlay shaft. At a depth of 30 feet the sinking was abandoned. No. 2 tunnel, 110 feet above the creek, cuts No. 2 reef some 50 feet from its mouth. The bearing of the reef here is 36° north of west. Here, also, a cross course has thrown the reef some 6 feet to the south.

"No. 3 tunnel is driven on Nos. 1 and 2 lodes at a height of 170 feet above the creek bed. No. 4 tunnel is also driven on these lodes at a height of 220 feet above the creek.

"Another vein, known as No. 3 lode, lies a little to the south of Nos. 1 and 2 lodes. Nos. 2 and 3 reefs are 15 feet apart in No. 2 level. The general dip of the reef is north-east at 80°."†

Jerry's Creek.—Near Crow Mountain, Parish Wilson, County Darling. Scheelite reported from this locality in north-west corner of parish.

Kelly Bros.' Scheelite and Tin Lode.—About 1 mile westerly from Stannifer. M.L. 30, Parish Herbert, County Gough.

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* Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 142.
† Mineral Resources No. 8. Rept. on Hillgrove Gold-field, 1900, p. 29.

Discovered by Kelly Bros. and P. Dwyer about 1905, and worked for about three years.

The lodestuff is chloritic granite, with prominent felspars. No defined strike observable. Worked by an open cut 30 feet deep and 25 feet long. A little trenching along the assumed strike to the south-east, and a little driving from the bottom of the open cut.

The width of lodestuff was about 9 feet at surface, but lessened with depth. About 14 tons of tinstone were obtained by roasting, crushing, and sieving.

The scheelite was similarly obtained as a marketable product, but the quantity secured is not known. A sample of the granitic lodestuff assayed in 1907 yielded:—

07-2075.—Tungstic trioxide..36 per cent.

Key's Scheelite Lode.—Hillgrove. Described by E. C. Andrews as—"have been proved for a distance of 320 feet along the lip of Baker's Creek Falls. It varies from 1 inch to 4 inches in width, and occurs in lenticular patches. Much of the ore won is found to contain over 60 per cent. of tungstic acid. From this lode, and another, but smaller, one lower down the hill, 20 tons were raised during last year.*

Kiarra Lode.—In Portion 116, Parish Metz, County Sandon, on north side of Hillgrove-Armidale road, near Baker's Creek Falls. Held as a 3-acre Mineral Lease by F. H. Gibson.

Discovered by Messrs. Gibson and H. Hubbert in May, 1907, in gneissic granite. The scheelite lens averaged about 2 inches in thickness for a horizontal distance of 57 feet, and was stoped to surface from 70 feet level; 20 tons of scheelite being obtained; the owners averaging £13 per week each. Below 70 feet, the rock becoming hard, the mine was sold to N. Hubbert, who continued the shaft to 110 feet and then abandoned it, though wages were made for some weeks. It was subsequently held by Turner Bros.

Lankey's Creek.—Musgrave Tin Lode. Scheelite and wolfram present in small proportion.

Macdonald's Veins.—Glen Creek, Parish Paradise North, County Gough. Honey-coloured translucent scheelite recorded here.†

Maddrick's Scheelite Lode.—Hillgrove. Described by E. C. Andrews as occurring "on the west side, and about half-way up the Baker's Creek Gully. It contains some pure scheelite; 17 tons were raised during the last half-year."‡ See also Centennial Scheelite Mine, p. 79.

Marobee.—Parish of, County Blaxland. M.L. 10 in this parish was taken up for tungsten ores.

Montreal Station.—Sixteen miles from Cooma. Scheelite from this locality was assayed in the Departmental Laboratory in 1910, and yielded as follows:—

10-294.—Tungstic trioxide.......... ....69 per cent.

Mt. Gifford, Lankey's Creek.—Parish Coppabella, County Goulburn.

G. W. Card records a red variety of scheelite, associated with galena and quartz, from this locality.§

Mt. Gifford Silver-lead Mine.—Authorities 35, 37, within Reserve 27,849, Parish Coppabella, County Goulburn.

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* Mineral Resources No. 8. Rept. on the Hillgrove Gold-field, 1900, p. 43. † David. Geol. Veg. Creek, 1887, pp. 161-2. ‡ Mineral Resources No. 8. Rept. on Hillgrove Gold-field, 1900, p. 43. § Records Geol. Survey N. S. Wales, 1907, VIII, Pt. 3, p. 3.

Scheelite was noted by the Writer in this mine in 1905, when inspecting the Coppabella Silver-lead discoveries. It occurred in small proportion in the above mine, associated with quartz, zinc-blende, galena, pyrites, and mispickel.* Probable the red variety described by Mr. Card came from the same lode.

Mulyan.—Parish of, County Wellington. M.L. 265 in this parish was taken up for scheelite.

Narragol.—Parish of, County Gordon. M.Ls. 174 and 187 in this parish were taken up for scheelite and wolfram.

Nundle.—In 1906, Inspector D. Milne reported scheelite at Pennyweight Flat, Nundle.†

G. W. Card also records scheelite as "massive in quartz."‡

M. Morrison, Senior Field Assistant, visited the Nundle District in March, 1910, and made the following notes on the occurrence of scheelite for the Writer:—

SCHEELITE AT NUNDLE.

"No mining was being done for scheelite in the Nundle district at the time of my visit.

"During the past four years desultory surface prospecting has been carried out at Happy Valley, about half a mile north-easterly of the post office, on what appears to be a belt of impregnated country rock. A quantity of scheelite associated with quartz and country rock was obtained on the surface.

"The country rocks are mainly slates and tuffs.

"While trenching on the hillside, with the object of locating a lode, W. Gazley obtained about 20 tons of stone containing scheelite. He estimates the stone contains about 15 per cent. tungstic acid, and proposes to crush and concentrate the ore. No defined lode has yet been found. Samples of scheelite associated with quartz and country rock were observed on some of the tips in the vicinity of Gazley's claim. A picked sample selected by me from one of the 'tips,' and assayed in the Departmental Laboratory, gave a return of 11·10 per cent. tungstic acid.

"The scheelite occurs within 10 chains of Paul's antimony shaft, and is almost on the direct line of strike of the lode worked there. The scheelite may possibly occur in this lode, but the very limited amount of prospecting so far carried out is not sufficient to enable me to say. At Foley's Folly, about 3 miles north-westerly from Hanging Rock, several reefs have been worked for scheelite, and small parcels of ore obtained. As far as could be ascertained the scheelite is associated with quartz, and occurs mostly where the reef bulges out. Three distinct lines of reef have been worked.

"During the past five years only about 1 ton of scheelite has been sent away from Nundle.

"Messrs. Travenor and party, working at Foley's Folly, disposed of 15 cwt. of ore, and still have about 5 cwt. on hand.

"Messrs. Sipple and party disposed of 5 cwt. last year and 70 lb. this year. The average price obtained was £100 per ton. Several small parcels varying from a few pounds up to 25 lb. weight, have been disposed of by different prospectors.

"Scheelite is said to occur in the Possum and Ruby Mine at Bowling Alley Point."

* Ann. Rept. Dept. Mines N. S. Wales, 1905, p. 148. † Ann. Rept. Dept. Mines N. S. Wales, 1906 p. 84. ‡ Records Geol. Survey N. S. Wales, 1907, VIII, Pt. 3, p. 3.

Oberon.—A sample of scheelite from this locality, submitted for assay in 1899, yielded :—

99-3203—Tungstic trioxide........................	68·37 per cent.

Parish Wilson.—County Darling. Between Barraba and Manilla, in Portions 134 and 135.

Scheelite from these portions, submitted for assay in 1907, yielded :—

07-2740—Tungstic trioxide..........	23 per cent.
Gold.......	5 dwt. per ton.

Peelwood.—A sample of scheelite or cupro-scheelite from Peelwood (probably from the Cordillera Mine in that locality) was assayed in the Departmental Laboratory, with the following results :—

41-1886—Tungstic trioxide	69·31	per cent.
Lime..	19·35	,,
Silica..	4·88	,,
Oxide of copper	4·05	,,
Oxide of iron	2·01	,,
	99·60	

Pepp's Flat, Copeton.—The tin ore which came down Two-mile Creek, from the high acid granite range at its head containing numerous stanniferous veins, at one spot close to the head of Pepp's Flat, was found by Mr. George White to be associated with a small quantity of scheelite and diamonds. The run of wash followed at this point dipped rapidly under the basalt sheet which forms the flat, and extends to Copeton. Water and the steep dip compelled cessation of operations.

Queanbeyan.—G. W. Card records scheelite with hornblende from Queanbeyan.*

Sofala.—Scheelite in small quantity in quartz is reported to occur near Sofala.

Top Lode, West Sunlight.—Portion 58, Parish Metz, County Sandon, adjoining the village of Metz, on the west side of Baker's Creek Gorge ; on the tableland just above the West Sunlight Gold Mine.

This lode was originally worked for antimony down to about 80 feet ; for scheelite in addition since December, 1909. The latter mineral has been followed down 60 feet below the 80 feet level, and the present shoot has been driven on for a length of 21 feet, with ore still in face on 19th May, 1911. Where quartz makes in the lode, the scheelite diminishes.

The Writer is indebted to Mr. E. McNamara for the following particulars of output from this portion of the lode to the date mentioned :—

	Scheelite.				Antimony.			
	tons.	cwt.	qrs.	lb.	tons.	cwt.	qrs.	lb.
McNamara's Workings, Portion 58......	5	16	1	10	27	3	1	13
Hardcastle's Workings, Portion 58......	0	9	3	17	6	0	0	25
Totals	6	6	0	27	33	3	2	10

Flood's line of lode in Portion 58, near the Top lode, strikes N. 40° W., and has been worked for scheelite down to 60 feet.

From this lode the following output of scheelite was obtained between March and October, 1907 :—

2 tons 13 cwt. 2 qrs. 19 lb.

* Records Geol. Survey N. S. Wales, 1900, VII, Pt. 2, p. 46.

Tuena.—1½ miles west. G. W. Card records a brown variety of scheelite with quartz from Tuena.* Its presence here was first noted in 1899, when a prospecting party was engaged opening a small but rich vein of scheelite, close to the Police Paddock, on the west of Tuena.† A sample assayed in 1905 (2827) yielded tungstic trioxide 36·63 per cent.

M. Morrison, Senior Field Assistant, visited the locality in April, 1911, and furnished data for the following notes :—

The scheelite occurs in small patches in a quartz reef, striking north and south in intercalated slate and limestone country. The locality being M.Ls. 113 and 114, Parish Yarraman, County Georgiana, a few chains west of the police paddock at Tuena.

So far only surface work has been carried out, proving the scheelite for a horizontal distance of about 70 feet, and a depth of 10 to 15 feet, but little or none is now visible. So far as could be learned no ore was raised unti 1910, when Messrs. Russell and party obtained about 1¼ tons of scheelite by sinking shallow holes along the strike of the reef, which appears to have been the total output to date.

Uralla.—Easterly, and 12 miles east. Samples of scheelite from this locality—so described—assayed in 1905, yielded :—

05-777—Tungstic trioxide........................41·45 per cent.

05-821—Tungstio trioxide.................. ......30·25 ,,

Usher's Lode, Hillgrove (now Damifino).—The aspect of this lode in 1904 is thus described by E. C. Andrews :—

"True fissure in solid granite near contact with slates. Strike about N. 30° W.; dip westerly, almost vertical. The outcrop has been proved over a distance of some 350 feet. The width of the vein varies from 2 to 6 inches. The scheelite at times was as much as 6 inches in width (in flat lenses). The gangue along the surface workings was mostly stibnite, very little quartz occurring. A tunnel was driven last year (1904) into the hillside to prove the reef at a lower level. At this depth (140 feet) the fissure was well defined, but narrower. The scheelite was some 2 to 3 inches in width, with a coating of stibnite on the hanging wall. Very little quartz was noticeable at this depth. The length of the outcrop (350 feet) may be taken as a fair measure of its probable continuation in depth."‡

See also p. .

Wood's Reef.—5 miles east, Barraba District. A sample of scheelite submitted for assay from this locality in 1905, yielded :—

05-593—Tungstic trioxide... .... 40·77 per cent.

Woolomin, about 4 miles south. Scheelite from this site, submitted for assay in 1908, yielded :—

08-3560—Tungstic trioxide........................69 per cent.

Yeoval. Taylor's Cyclops Copper Mine, Lower Tinby.—Portion 93, Parish Obley, County Gordon.

The occurrence of cupro-scheelite in this mine has been described by G. W. Card as follows :—

"This mineral has recently been detected at Taylor's Copper Mine, Upper [Lower.—J.E.C.] Tinby, close to Yeoval. The ore consists of bornite, with copper carbonates, and the cupro-scheelite is closely associated with it. It is waxy in appearance, and, while sometimes

* Records Geol. Survey N. S. Wales, VII, Pt. 2, 1902, p. 46. † Ann. Rept. Dept. Mines N. S. Wales 1899, p. 76. ‡ Ann. Rept. Dept. Mines N. S. Wales, 1904, p. 142.

whiter, is generally of a greenish tint. In places retangular outlines can be seen. Cupro-scheelite is known to occur at Peelwood [Cordillera Hill.—J.E.C.], where it is intimately associated with scheelite and stolzite. An analysis of a sample picked from the material most nearly free from colour, gave results as follows:—

	Per cent.
Moisture and combined water	2·55
Tungstic trioxide	57·73 (66·7)
Lime	14·40
Magnesia	0·22
Ferric oxide	2·98
Alumina	trace
Copper oxide	7·08 (8·18)
Molybdic oxide	trace
Carbonic oxide	1·56
Gangue	13·04
	99·56

"Neglecting the gangue, and re-calculating, the percentages of copper and tungstic trioxide become respectively 8·18 and 66·7. The percentage of tungstic trioxide is rather low, but there is not enough carbonic acid to account for the copper."*

* Records Geol. Survey N. S. Wales, V, 1896-8, p. 122.

VIIb.—CUPRO-SCHEELITE DEPOSITS.

Cupro-Scheelite.

Back Creek, near Rockley.—Parish Rockley, County Georgiana. Cupro-scheelite is reported from this locality.

Cordillera Hill.—Parish Cordillera, County Georgiana, Tuena district.

Scheelite, cupro-scheelite, and stolzite were discovered in the Cordillera Hill silver and copper lode in 1888, but these minerals were not specifically searched for.

A sample of massive cupro-scheelite of a dark greenish colour yielded—

Tungstic trioxide	69·31	per cent.
Lime	19·35	,,
Silica	4·88	,,
Copper oxide	4·05	,,
Iron oxide	2·01	,,
	99·60	

Prior to this date, Mr. W. A. Dixon, F.I.C., F.C.S., detected the presence of *stolzite* (tungstate of lead) in the above lode.

Orange.—Cupro-scheelite from this locality was assayed in 1899 for the following return:—

99–3985—Tungstic trioxide	68·35	per cent.
Metallic copper	2·56	,,

VIIc.—STOLZITE (TUNGSTATE OF LEAD) OCCURRENCES.

Alick Steyne Creek.—Parish Highland Home, County Gough.

Stolzite is recorded by G. W. Card from this locality, associated with wolfram and scheelite.*

Broken Hill Lode.—*Stolzite* was obtained in the oxidised zone of this lode.

G. W. Card described its occurrence as follows:—

> "This comparatively rare mineral, a tungstate of lead, is now being found in at least two different forms. One variety is of a grey colour, with a pearly lustre, and resembles the head of a nail in appearance, the crystals consisting of faces of the tetragonal prism, terminated by a low pyramid of the same order.
>
> "The other variety is apparently only found in the Open Cut at the Proprietary Mine. It is yellow-brown in colour, and the crystals consist essentially of the tetragonal prism. The basal plane and pyramid of different order are sometimes present. One of the largest crystals has a length of nearly a centimetre."†

Another form is described as "claret-coloured, pyramidal, perhaps hemihedral."‡

C. Hlawatsch has described Broken Hill stolzite in yellow and reddish crystals, and quoted the following analysis by Professor Treadwell, of Zurich:—§

Tungstic trioxide (WO_3)	51·34	per cent.
Lead oxide (PbO)	47·44	,,
Manganese oxide (MnO)	0·78	,,
Magnesia (MgO)	trace	
	99·56	

Emmaville, near.—A sample of stolzite from the locality thus broadly defined was submitted for assay in 1905, and yielded—

05-5443	Tungstic trioxide	57·1	per cent.
	Metallic lead	9·49	,,

* Records Geol. Survey N. S. Wales, VIII, 1905-9, Pt. 3, p. 259.
† Records Geol. Survey N. S. Wales, 896, V, Pt. 1, p. 8.
‡ *Op. cit.*, Pt. 3, p. 122.
§ Records Geol. Survey N. S. Wales, VI, pp. 53 to 57

VIII.—METALLIC MINERALS ASSOCIATED WITH TUNGSTEN ORES.

Bismuth is an invariable associate of the tungsten deposits of the Mole Tableland, though occurring in varying proportions; the richest occurrence being in the "Bismuth" Mine of the Torrington Ore Company, Limited, where native and sulphide of bismuth is in commercial quantity in the pegmatite lodestuff worked in that mine. The wolfram concentrates from this mine and Fielder's Hill (which are worked in conjunction) average about 6 to 8 per cent. of bismuth.

In the essentially wolfram mines, bismuth ores of considerable richness occur occasionally in more or less limited quantity; but the general average yield is below the commercial limit, at least so far as the sellers are concerned. At Mount Everard some rich carbonate and oxide (and lesser native bismuth) have been obtained.

Antimony (stibnite) is a common associate of scheelite at Hillgrove, the former predominating in many of the auriferous lodes of the district. The low and uncertain value of antimony has hitherto prevented vigorous development for that metal alone. The increased value of scheelite may, however, lead to their reopening, as the two minerals are separable over concentrating tables into commercial grades.

Molybdenite is also a common associate of wolfram, but not in workable proportion in the principal field. At Kingsgate, 18 miles easterly from Glen Innes, in the famous Sach's Mine, phenomenally massive molybdenite occurred, blocks up to 600 lb. of pure ore being obtained. Here a payable concentrate of molybdenite and bismuth was obtained over vanners for some years.

Cobalt, in the form of smaltine (arsenide), occurs in the Bismuth Mine, near Torrington, for an analysis of which see page 71.

Ilmenite (titaniferous iron) is present in some of the Torrington lodes; and in one instance at Cow Flat is reported to have cut out the wolfram.

Cassiterite is not actually associated with the wolfram at Torrington, but occurs in close proximity at Fielder's Hill—where small parallel seams occur in a neighbouring outcrop.

At the Glen Eden Mine, Hogue's Creek, near Dundee, it is more intimately connected; rich veins of finely-crystallized cassiterite occurring in the wolfram-bearing lodes.

Cassiterite is also closely associated with wolfram at Pulletop and Jingellic.

Copper and arsenical pyrites frequently occur in the Gulf wolfram lodes but are not conspicuous at Torrington.

VIIIa.—NON-METALLIC MINERALS ASSOCIATED WITH TUNGSTEN DEPOSITS.

Monazite is a common, but not abundant, associate of the tin and tungsten deposits of New England, as well as of the beach sands of the North Coast. The chief value of this complex mixture of rare earths depends upon its thoria contents. The utilization of the latter in the preparation of incandescent mantels for gas burners directed considerable attention to monazite. Numerous samples from widely separated localities have been assayed, but in rare instances only has the commercial minimum of thoria (2 per cent.) been reached.

W. A. Dixon, in 1881, analysed a sample of monazite from Vegetable Creek district, with the following results :—

Phosphoric acid	25·09
Oxide of cerium	36·64
,, lanthanum	30·21 (lanthanum and didymium together)
,, didymium	
,, thorium	1·23
,, manganese	traces
,, magnesium	traces
,, aluminium	3·11
Silica	3·21
	99·49

"The mineral was crystalline, but the crystals were broken and ill-defined. One piece, however, appeared to be a monoclinic prism. Colour, yellowish red, in thin pieces semi-transparent; it gave a white streak, showing a hardness about 5; it was rather brittle, and gave a yellowish powder infusible before the blow-pipe."*

C. S. Wilkinson, in 1883, recorded monazite in this district, about 20 chains from Butchart's Nugget Mine in Portions 9 and 10, Parish Muir, County Gough. It was here associated with amethystine quartz, fluor-spar, and pyrites.

In 1903, J. C. H. Mingaye† analysed a sample of monazite from 11 miles north-west of Deepwater (about Battery Mountain), with the following result‡ :—

03-2930—Oxide of Cerium, Ce_2O_3	70·71 per cent. (Cerium, Lanthanum, Didymium and Yttrium together)
,, Lanthanum, La_2O_3	
,, Didymium, Di_2O_3	
,, Yttrium, Y_2O_3	
,, Thorium, ThO_2	·77 ,,

Monazite from "Black Swamp" was assayed by J. C. H. Mingaye with a view of determination of its thoria contents, with the following results :—

No. 07-7725—	I. Per cent.	II. Per cent.
Rare earths of the Cerium group, as oxides, including thoria (ThO_2).	69·40	69·28
Thoria (ThO_2)	4·12	4·10
Phosphoric anhydride (P_2O_5)	25·75	......

"This sample is the best so far examined of the New South Wales monazites, and, if it occurs in sufficient quantity, should prove of commercial value for the extraction of the thoria contents."§ (It is not, however, in commercial quantity.—J.E.C.)

* Ann. Rept. Dept. Mines N. S. Wales, 1881, p. 36.
† Mr. Mingaye, in 1909, published a paper on "Experiments on the Estimation of Thoria in Monazite." Records Geol. Survey N. S. Wales, VIII, 1909, Pt. 4, pp. 276-286.
‡ Ann. Rept. Dept. Mines N. S. Wales, 1903, p. 138.
§ Records Geol. Survey N. S. Wales, VIII, 1905-9, Pt. 4, p. 283.

The following samples of monazite-bearing sands have been examined from Torrington and The Gulf:—

Per cent.

	849/04	879/04	880/04	1178/04	1179/04	1567/04	2493/04	3033/04	3131/04	3401/04
Oxide of the rare earths of the Cerium Group —*i.e.*, Ce_2O_3, La_2O_3, Di_2O_3, Y_2O_3.	29·30	72·30	67·12	63·39	54·37	41·84	71·11	17·03	15·15	22·45
Thoria (ThO_2)	0·65	0·38	0·71	1·56	1·81	0·31	0·35	0·75	....	....
Metallic Bismuth........	..	..	4·98	..		..	..	..	....	....
Metallic Tin	..	..	..	..	..	..	..	..	....	....
Chromium Sesquioxide..	..	..	..	..	..	..	..	0·35	....	....
									oz. dwt. grs. per ton.	oz. dwt. grs. per ton.
Fine Gold	..	..	..	..	..	..	..	..	1 19 4	0 19 12
Platinum	..	..	..	..	..	..	..	..	....	1 4 11

Nos. 879, 880—From Torrington.
,, 1178, 1179—20 miles west of Torrington.
,, 849, 1567, 2493—The Gulf, Emmaville district.
,, 3033—Camden Haven }
,, 3131—Tacking Point } Beach sands.
,, 3401—Port Macquarie }

Monazite, as already mentioned, is an associate of gold, platinum, and cassiterite in the North Coast beach sands, particularly between the Clarence and Richmond River heads. The following analyses by J. C. H. Mingaye* are given for comparison with the Torrington and Gulf mineral.

The samples analysed consisted of highly concentrated sand from Broken Head, Ballina, near the mouth of the Richmond River. The average proportion of monazite in the beach sands is infinitesimal, and it is only in reconcentration of the carpet concentrates obtained in winning the gold and platinum that an appreciable quantity is obtainable:—

	I.	II.
Phosphoric anhydride (P_2O_5)	18·89	18·94
Oxide of Cerium (C_2O_3)......................	22·42	22·72
,, Lanthanum (La_2O_3) .... } ,, Didymium (Di_2O_3) .... }	22·95	22·78
,, Yttrium (Y_2O_3)	·16	not determined.
,, Thorium (ThO_2)......................	·46	·57
Silica (SiO_2)...................................	6·68	6·48
Alumina (Al_2O_3)...............................	·14	·19
Ferric oxide (Fe_2O_3)	2·08	1·96
Manganous oxide (MnO)	trace	trace
Lime (CaO)...	1·32	1·40
Magnesia (MgO)..................................	trace	trace
Oxide of Zirconium (ZrO_2)	15·36	15·44
,, Tin† (SnO_2)............................	9·03	9·12
,, Tantalum (Ta_2O_5)	1·10	·86
,, Titanium (TiO_2)	absent	absent
Water (H_2O)	·10	·12
	100·69	100·58

Fluor-spar is a common associate, and at Rumsby's Lode, at The Gulf, it formed a considerable part of the matrix, large masses of rich green fluor-spar being obtainable; in part well crystallized.

At the Torrington lodes it is present, but not in appreciable quantity.

* Records Geol. Survey N. S. Wales, Vol. VII, 1903, p. 222.

† Metallic tin, 7·11 per cent.

Topaz, both massive and crystallized, is common in the Torrington ore-rock; in fact, Mr. G. W. Card, on microscopic examination, found it to be one of the constituents of the lode-rock. It is readily recognised in many of the outcrops, and particularly at the new quarry in Hawkins' Lease, at Black Swamp. Doubtless the numerous water-worn topazes found during early tin-mining in the channels and leads of the district, were derived from this rock, and from the parent granite massif.

It is interesting to note that topaz was first noted in New South Wales in 1811.*

Beryl occurs in particularly fine crystals as regards form. Heffernan Bros.' Mine (M.L. 52, Parish Highland Home, County Gough) furnishing some of the best presented to the Mining Museum.

Smith's Lease (M.L. 65, Parish Rock Vale, County Clive) affords slender acicular crystals in biotite. This gem in water-worn pebbles was also common in the early alluvial tin leads.

Lithia-bearing Mica occurs at the Bismuth Mine, and possibly at Smith's Lease, as pointed out by G. W. Card (page 42). The percentage of lithia, however, is so small as to raise doubt whether it is sufficient to remove the mica from the ordinary biotite group.

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* G. Paterson, History of N. S. Wales, 1811, p. 43.

IX.—STATISTICS.

Hillgrove District.—Scheelite is the only tungsten mineral occurring in this district, and this is the only locality so far discovered in the State where it occurs in commercial quantities. The first authentic record of its occurrence was in 1886, when a sample from Gara Falls tested in the Departmental Laboratory yielded 47·9 per cent. of tungstic acid.*

In this year also a sample from near Peelwood yielded 69·31,† probably from the known occurrence at Cordillera Hill.

In 1887 it was recorded that scheelite occurred at Hillgrove, but was not being worked.

In 1892 attention began to be directed to the Hillgrove deposits, for twenty-two assays of scheelite were made during that year, ranging from 38 to 71 per cent. of tungstic acid.

In 1893 samples of scheelite with stibnite from Hillgrove were assayed for 51·23 and 71·65 per cent. of tungstic acid.

Mining evidently did not begin until 1898, when about 1¼ tons of scheelite valued at about £30, are recorded as having been obtained from the Hopetoun Mine. The ore appeared as a small shoot, but soon pinched out.‡

Active operations ensued in 1899, 70 tons being sold, valued at £2,750. During the last quarter of the year 76 tons were raised. The Hopetoun Syndicate (Metz) sold 4 tons at an average of £40 per ton, and at the close of the year had 70 tons of undressed ore at grass. Between thirty and forty men were employed on the antimony and scheelite patches.§

During 1900 scheelite was won in the Hillgrove field, the quality varying from 50 to 60 per cent. of tungstic acid. Deducting the value of wolfram exported, that of scheelite reached £1,782.

During 1901 the total value of the output of tungsten minerals only amounted to £163, the serious fall in values checking operations.

Apparently none were exported in 1902.

In 1903 Hillgrove furnished 3 tons of scheelite, valued at £140. Little work was done, as the demand was slight.

During 1904 satisfactory values gave an impetus to mining, 15½ tons of scheelite being exported, of a value of £1,406.

In 1905 the output increased to 138·30 tons, valued at £10,122. About fifty miners were employed scheelite mining. The average local price obtained was £65 per ton.

In 1906 the output of scheelite—practically all from Hillgrove—amounted to 109·4 tons, valued at £7,647, the greater proportion coming from Miller's Freehold.

During 1907 the export amounted to 196 tons, valued at £23,781. Values fluctuated greatly during the year—ranging from £50 to £150 per ton for concentrates.

In 1908 153·7 tons were raised, valued at £11,082, the best results being obtained from Miller's Freehold, Portion 116, Parish Metz, County Sandon.

* Ann. Rept. Dept. Mines N. S. Wales, 1886, p. 41. † *Ibid.* ‡ *Ibid.*, 1898, p. 75. § *Ibid.*, 1899, p. 76.

The yield for 1909 amounted to 193·30 tons, valued at £14,618. The local prices ranged from £65 to £130 per ton of 72 per cent. ore, the two chief producing mines being those of W. H. Cranston and party and E McNamara's.

In 1910 the output was 150·6 tons, valued at £15,747. The local prices averaged £103 per ton during the year.

Total output of Scheelite in New South Wales from 1898 to 1910 :—

Year.	Quantity.	Value.	Remarks.
	tons.	£	
1898	1·25	30	From Hopetoun Mine, Hillgrove.
1899	70·0	2,750	
1900	45·3	1,782	
1901	....	....	£163 total for scheelite and wolfram.
1902	....	....	No output.
1903	3·0	140	
1904	15·5	1,406	
1905	138·3	10,122	
1906	109·4	7,647	
1907	199·15	24,163	3·15 tons included from Nundle.
1908	153·7	11,082	
1909	193·3	14,618	
1910	150·6	15,747	1·25 tons included from Tuena.
	1,079·50	£90,787	

List of Scheelite Leases in force at Hillgrove in May, 1911 :—

Name.	Area.			Parish.	County.	Portion No.
	a.	r.	p.			
Henry George Maddrick	2	0	0	Metz	Sandon	Part of forfeited M.L. 30.
Thomas Pedlow	4	0	0	do	do	M.L. 51
Harvey Hubbert	5	3	37	do	do	M.L. 41
Joseph White	5	0	0	do	do	M.L. 63
Michael Cox, Samuel Hoydon, and Isaac Hogue.	2	0	0	do	do	M.L. 82
Thomas Keys	5	0	0	Cooney	do	M.L. 33
Oliver Scott Rowe	1	0	0	Metz	do	M.L. 81
Archibald Milton Hoyes	10	0	0	Cooney	do	M.L. 32
Edward Cleary McNamara	5	0	0	Metz	do	M.L. 17
Thomas Perks	0	2	2	do	do	M.T. 17
Francis Henry Gibson	8	0	0	do	do	M.L. 80
Walter Maddrick	20	0	0	do	do	M.L. 79
Henry George Maddrick	12	1	25	do	do	M.L. 38
John Charles Ross	5	0	0	do	do	M.L. 16
Cosmopolitan G. M. Company	6	2	0	do	do	G.L. 37
William Henry Logan	5	0	0	do	do	M.L. 74
Patrick Denis Ryan	2	0	37	do	do	M.T. 16
Henry George Maddrick	2	0	0	do	do	M.L. 73
William L. Smith	6	0	10	do	do	P.M.L. 6
Patrick Denis Ryan	1	0	0	do	do	M.L. 72
William H. Cranston	1	0	0	do	do	M.P.L. 5
Nelson Hubbert	3	0	0	do	do	P.M.L. 4
James Selby	5	0	0	do	do	P.M.L. 6
Robert Sharp	1	2	0	do	do	M.L. 70

Output of tungsten ores in New South Wales during 1910:—

TUNGSTEN ORES.*

Scheelite.

"The quantity of scheelite exported during the year is 150·6 tons, valued at £15,747, as compared with 193·3 tons, valued at £14,618, in 1909.

"In the Hillgrove Division, numbers of men were engaged searching for this mineral, and generally were rewarded with fair returns. The surface veins, however, are being gradually worked out. The matter of prosecuting work at the deeper levels was engaging attention at the close of the year, and it was proposed to reopen and systematically develop several of the old mines. The price paid on this field during the period under review averaged £103 per ton for 70 per cent. ore.

"A parcel of 1·25 tons of scheelite was obtained from the Tuena Division.

Wolfram.

"The quantity of wolfram exported during 1910 amounted to 165·67 tons, valued at £16,258, as compared with 127 tons, valued at £11,249, in the year 1909.

"In the neighbourhood of Torrington, in the Deepwater Division, con siderable activity was manifested, £20,000 approximately being spent in the erection of reduction plants. The principal producers were:—The Torrington Ore Company (Limited), the Rockvale Wolfram Mines, and the New Hope Wolfram Mining Company.

"In the Glen Innes Division, the mine on the private property of E. J. Newsome was worked by W. J. Gould, the output being valued at £700.

"From Pulletop, in the Wagga Wagga Division, some 15 tons of wolfram ore were obtained."

TOTAL output of Wolfram in New South Wales (compiled from Mineral Resources, 1901, and the Annual Reports of the Department of Mines).

Year.	Tons.	Value.	Remarks.
		£	
1891	7·00	70	
1892	......	......	No record.
1893	1·38	14	
1894	......	......	No record.
1895	5·00	88	
1896	......	.....	No record.
1897	......	......	No record.
1898	9·00	280	
1899	......	......	No record.
1900	5·25	315	
1901	......	163	Fall in value checked operations.
1902	......	.....	No record.
1903	9·00	608	Demand slight; little work done.
1904	89·00	8,432	
1905	86·50	7,361	Small quantities from Wilson's Downfall, Glen Innes, Pulletop, Berridale, and Frogmore.
1906	132·15	9,057	
1907	206·75	26,235	£15,187 from Torrington Ore Company; £2,400 from Wentworth Proprietary; £403 from Wilson's Downfall.
1908	86·15	6,742	Torrington Ore Company closed from March to October owing to low price of mineral.
1909	127·00	11,249	Torrington Ore Company treated 10,455 tons of ore for 93 tons of concentrates; New Hope Company obtained 25 tons.
1910	165·67	16,258	About £20,000 spent in erection of new reduction plants.
	929·85	£88,068	

* Ann. Rept. Dept. Mines N.S. Wales, 1910, p. 57.

COMMONWEALTH OF AUSTRALIA.

RODUCTION of Tungsten Ores from 1900-1910.—Compiled from Annual Reports of the Departments of Mines, the Queensland *Mining Journal* (1910), and Official Year Book of the Commonwealth.

ear.	New South Wales.		Victoria.		Queensland.		South Australia (Northern Territory).		West Australia.		Tasmania.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Qu-ntity.	Value.	Quantity.	Value.
	tons.	£	tons.	£	tons.	£	tons.	£	tons.	£	tons.	£
900	(?)	1,913	....	....	189·5	6,605	....	....	....	....	53·75	2,058
901	(?)	163	....	....	72·0	1,145	....	....	....	....	....	....
902	....	....	....	....	55·0	1,167	. ..	....	....	....	....	....
903	18·0	420	....	....	197·0	7,870	....	....	....	....	....	....
904	104·5	9,578	....	....	1,539·5	161,710	....	...	....	....	15·5	1,147
905	224·8	17,483	....	....	1,413·0	100,203	....	....	. ..	....	32.25	2,371
906	241·6	16,704	....	....	772·5	64,483	....	7,000	....	....	19·75	1,465
907	402·7	50,016	....	....	617·5	90,087	....	11,450	....	....	40·75	4,411
908	239·8	17,824	3	252	420·7	32,792	....	542	....	....	4·5	338
909	320·3	25,867	14	1,432	606·2	56,348	....	4,105	1	90	28·35	2,494
910	317·5	32,110	28	2,092	879·4	90,761	....	....	2	190	67·35	7,280
	1,869·2	172,078	45	3,776	7,262·3	613,171	....	....	3	280	262·20	21,564

Total production of tungsten ores in New South Wales to end of 1910, 2,013·6 tons ; value, £178,960.

WORLD'S Production of Tungsten Ore, 1905–1909, by countries, estimated in short tons of concentrates containing 60 per cent. of tungsten trioxide.*

Country.	1905.	1906.	1907.	1908.	1909.
Africa—South Africa	......	9	211	40	16
Asia –					
Federated Malay States	......	151	89	83	99
Siam	......	..	10	...	...
India	.. ...	...	......	...	7
Australia—					
New South Wales	251	270	451	268	431
Northern Territory	71	230	177	9	49
Queensland	1,582	865	703	516	679
Tasmania	36	22	46	5	20
Victoria	......	...	.....	3	15
Western Australia	......	...	1	...	6
East Indies—					
Billiton	......	...	4	11	...
Singkep	......	...	1	14	23
Europe –					
Austria	65	63	50	44	43
England	193	304	361	261	421
France	28	20	67	124	...
German Empire	42	57	68	46	106
Italy	35	28	18	...	..
Portugal	320	629	702	684	609
Spain	413	222	303	249	...
Oceania—New Zealand	64	121	153	87	78
North America—United States	803	928	1,640	671	1,619
South America—					
Argentina	.....	326	507	548	900
Bolivia	75	75	500	187	168
Brazil	......	..	......	16	...
Total	3,979	4,320	6,062	3,898	5,289

* Min. Resources, Geol. Survey—Quoted by the Mineral Industry, XIX, 1910, p. 665.

UNITED STATES production of Tungsten Ores from 1900 to 1910, inclusive.*

Year.	Quantity.	Value in dollars.
	short tons.	$
1900	46	11,040
1901	179	27,720
1902	184	34,040
1903	292	43,639
1904	740	184,000
1905	803	268,676
1906	928	348,867†
1907	1,640	890,048†
1908	671	229,955†
1909	1,619	614,370†
1910	2,020	844,526

PRICES.

The following diagram (after O. J. Steinhart, the Mineral Industry, XVII, 1908, p. 826, with additions from London quotations in the *Australian Mining Standard*) illustrates at a glance the extreme fluctuations in market value of tungsten ores per unit in the past, and their more equable range during the past two years. :—

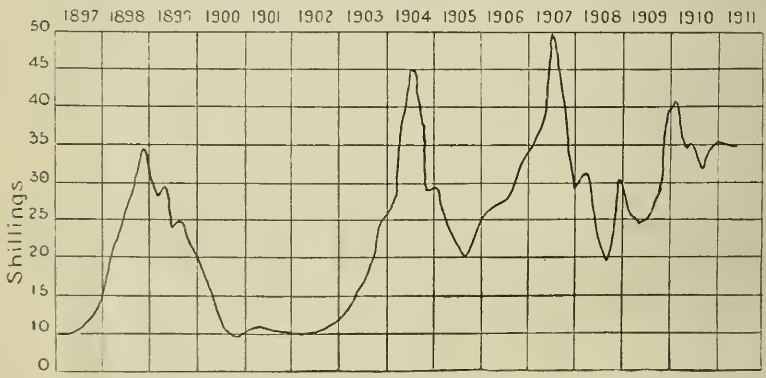

FIG. 12.

The value of the concentrates, apart from the percentage of tungstic oxide, is affected by the freedom or otherwise from impurities, such as phosphorus and sulphur.

According to the Bulletin of the Imperial Institute,† "information as to the actual basis of purchase is not readily obtainable, but it is stated that the phosphorus and sulphur should not much exceed 0·25 and 0·01 per cent. respectively."

* Statistics reported by the U.S. Geol. Survey, except for 1910. The Mineral Industry, XIX, 1910, p. 661.

† Vol. VII, No. 3, 1909, p. 291.

‡ Since the beginning of 1906, the figures have been, as far as possible, made to represent the equivalent of ores carrying 60 per cent. WO_3, which is the ordinary commercial basis in the United States.

GEOLOGICAL MAP

SHOWING THE

MOLE TABLELAND WOLFRAM DEPOSITS

NEAR TORRINGTON

Geologically surveyed by J. E. CARNE, F.G.S., Assistant Government Geologist.

Prepared under the direction of E. F. PITTMAN, A.R.S.M., Government Geologist, Department of Mines, New South Wales, 1911.

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